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**JUSTIFICATION OF ESTIMATES FOR FISCAL YEAR 1987  
SUBMITTED TO CONGRESS**

**FEBRUARY 1986**



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**DEFENSE ADVANCED RESEARCH  
PROJECTS AGENCY**

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# FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: 61101E  
USDR&E Mission Area: 530

Title: Defense Research Sciences  
Budget Activity: 1. Technology Base

## A. RESOURCES (PROJECT LISTING): (\$ in Thousands)

Project Number	Title	FY 1985 Actual	FY 1986 Estimate	FY 1987 Estimate	FY 1988 Estimate	Additional to Completion	Total Estimated Costs
	TOTAL FOR PROGRAM ELEMENT	74,807	87,500	95,900	113,400	Continuing	N/A
MS-1	Materials Sciences	10,961	15,875	19,810	26,500	Continuing	N/A
ES-1	Electronic Sciences	16,298	17,570	24,300	25,800	Continuing	N/A
DRH-1	Systems Sciences	12,162	14,430	14,075	21,700	Continuing	N/A
CCS	Computer and Communications Sciences						
CCS-2	Advanced Digital Structures and Network Concepts	19,351	22,020	22,500	23,300	Continuing	N/A
CCS-3	Modernization Technology	8,922	8,375	7,400	8,300	Continuing	N/A
UDR-1	Unconventional Detection Research	1,783	-0-	-0-	-0-	-0-	41,420
UDR-2	Power Source and Extra Hypervelocity Technology	1,690	4,830	5,400	5,300	Continuing	N/A
DRT-1	Targ Penetration Research	1,450	2,100	-0-	-0-	Continuing	N/A
DRG-1	Geophysical Research	2,190	2,300	2,415	2,500	Continuing	N/A

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B. BRIEF DESCRIPTION OF ELEMENT AND MISSION NEED:

Materials Sciences. This project explores new materials, processes, structures, and device concepts, and demonstrates innovative solutions for overcoming materials-related limitations or barriers to advancements in: rapid-solidification technology; improved propulsion engine materials; metal-matrix composites; ceramics and ceramic matrix composites; laser countermeasure materials; synthesis of stronger and more heat resistant polymers and adhesives; solid lubrication; materials response at high strain rates; radar absorbing materials and structures; battlefield optical sensor protection; and electromagnetic processing of materials.

Electronic Sciences. This project explores new concepts in electronic materials, devices, and device fabrication with the goal of demonstrating their feasibility to provide new technical options for implementing future electronic systems. Strong emphasis is placed on pursuit of unique combinations of performance, survivability, and cost required of DoD systems. Technologies pursued include: digital integrated circuits, millimeter wave and optoelectronic circuits of submicron feature size utilizing either compound semiconductors or silicon; electro-optical (especially infrared) sensors; optical computing and processing materials and devices; monomolecular and electronically active polymer films; and special devices and materials of particular interest to DoD.

Systems Sciences. The objective of this program is to carry out highly innovative, small scale, interdisciplinary systems research leading to improved effectiveness of Armed Forces personnel in accomplishing their mission responsibilities. This program is organized around four research areas: technology for the development of command and control support systems; systems for land based travel; systems for autonomous navigation; and development of the advanced biochemical technology base for broad-based defense and intelligence applications.

Computer and Communications Sciences. This program supports basic research in information processing and computer communication technology to provide a technological base for the development of future intelligent, network-based, military systems and for improved productivity through automation. The focus is on basic concept development, and includes the development and exploitation of advanced concepts in robotic software and automation technology design systems, advanced system network concepts, and Very Large Scale Integration (VLSI) architecture and design. User interface technology is being developed to offer

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more effective and efficient access to computers and tactical weapon systems. A modernization technology effort is providing experimental computer resources to improve research productivity at the forefront of computer science, and developing advanced VLSI design systems, advanced control and manipulation techniques and increased defense manufacturing productivity through the use of advanced automation techniques. Experimental computer resources are being provided to major universities in order to upgrade their resources to adequately support their DoD research. This portion of the program will continue through FY 1988.

Power Source and Extra Hypervelocity Technology. The objectives of this project are to investigate new materials, processes, structures and demonstrate innovative solutions for overcoming materials related limitations or barriers to advancements in direct chemical to electrical energy conversion, and extremely high power density electrical charge storage. Objectives of the Extra Hypervelocity Technology program are to investigate physical phenomena, materials modification, and impact phenomena. There is a need to greatly improve the performance of: airborne and ground vehicle prime electrical power sources that will permit reduced thermal, acoustic and air inlet radar signatures; high power density electrical charge storage components that can be utilized by a number of advanced weapon system and vehicle concepts requiring high power, short duration sources; and projectilelaunching weapon systems, supersonic air vehicles, advanced reentry bodies and advanced heavy armor targets. Other activities to which the ultracapacitor and fuel cell technologies are relevant include the entire field of high power directed energy weapon and lower power remotely powered vehicles (including U.S. Navy, Army and Air Force application).

Target Penetration Research. This project supports basic research activities in the areas of penetration mechanics, high-performance materials, shaped charge jetting phenomena, and advanced warhead concepts. Also included in the program are theoretical studies of chemical hydrodynamics and combustion/ explosion phenomena. Useful results of these various studies are applied to on-going related activities in exploratory development.

Geophysical Research. This program is aimed at conducting basic research and development to enhance U.S. capabilities for monitoring nuclear explosion events. Consideration of a nuclear test ban requires detailed technical information on explosion driven seismic sources, high frequency, seismic wave propagation, and procedures to differentiate explosion signals from those occurring naturally (earthquakes). A nuclear test ban would require the highest possible level of monitoring capability to verify that the Soviet's were

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or were not employing evasive techniques and to reduce the number of possible false claims of cheating. This capability rests on a foundation of basic seismological geophysics which is extended and maintained through DARPA funding of university research. This basic research also leads directly to improvements in the U.S. ability to estimate the yields of Soviet underground explosions and thus to evaluate their weapons program and to verify compliance or non-compliance with the Threshold Test Ban Treaty.

C. COMPARISON WITH FY 1986 DESCRIPTIVE SUMMARY:

Materials Sciences. Reductions in this project are due to fewer new initiatives being pursued as a result of general budget reduction requirements.

Electronic Sciences. The funding increase in this project will support new research opportunities in molecular beam epitaxy (MBE) to study electronic phenomena in superlattices. New device structures as well as new physical principles will be pursued towards achieving higher performance electronic devices for millimeter wave phased array radars and/or infrared imaging systems. Increased funding also will expand research in optical symbolic computing. Recent progress in this area strongly suggests that this technology may provide substantial advances in processing of imagery for target recognition, guidance, and other systems needs.

Computer and Communications Sciences. Reductions for the Advanced Digital Structures and Network Concepts project reflect cutback in planned funding for enhanced capability modifications for the adaptive network program in response to general budget reduction requirements. Reduction for the Modernization Technology project reflect changes to planned computer resources and software support expenditures as a result of general budget reduction requirements.

Target Penetration Research. The funding for this project was transferred to PE 62702E due to the maturing of the research and the more applied nature of the research results.

D. OTHER APPROPRIATIONS. Not Applicable.

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E. RELATED ACTIVITIES:

Materials Sciences. DARPA programs in metal matrix composites, rapid solidification technology, solid lubrication, optical sensor protection, advanced ceramics, and high temperature polymers and adhesives are coordinated with other service efforts and other agencies through a number of committees and interagency groups, including: National Science Foundation, Interagency Materials Coordinating Committee; Interagency Working Group on Ceramics for Heat Engines; Interagency Committees on Rapid Solidification and Metal Matrix Composites; and Tri-Service Laser Hardened Materials Working Group.

Electronic Sciences. The Services have programs developing specific infrared sensor devices. The DARPA program is focused on demonstration of new "silicon-like" material growth, processing, and characterization for infrared sensor arrays, principally on the material mercury cadmium telluride. The DARPA programs in optical processing complement the algorithm and architecture programs of the Air Force Office of Scientific Research with efforts in material and device development. The research effort in submicron device and materials technology complements the USDR&E Very High Speed Integrated Circuits (VHSIC) program by addressing long range problems in design and fabrication of materials and devices that operate at or very near their physical limits and are fabricated in high vacuum via in-situ combinations of beam processing steps. A number of efforts are funded cooperatively with the Air Force, Navy, and Army Office of Research, Air Force Wright Aeronautical Laboratories Materials Division, and the Naval Ocean Systems Command. Cooperative research efforts with the National Science Foundation at universities concerning use of synchrotron radiation, submicron structures, and crystal growth research are in progress.

Systems Sciences. These efforts are coordinated with Army Research Institute, Battlefield Information Systems Program; Defense Mapping Agency; Army Intelligence Center and School; Army Armor Center; Army Tank Automotive Command; Air Force Rome Air Development Center; Air Force Wright Aeronautical Laboratories, and Army Engineering Topographic Laboratories. Chemical ultrasound research is closely coordinated with the Army and complements their efforts by focussing on long range materials production processing, integration, and device design concept issues.

Computer and Communications Sciences. The multi-Service effort on Very High Speed Integrated Circuits (VHSIC) is focused on very high speed technology and complements the DARPA program which is addressing architecture and design concepts for very large scale systems. The National Science Foundation (NSF) has a

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basic research program in submicron structures which is being coordinated with the DARPA program. DARPA maintains close technical liaison with the Defense Communication Agency on new computer communications protocols and advanced network concepts. NSF and the military services are also providing sorely needed computer equipment to research institutions and some industry vendors are offering sizeable discounts to universities. NSF, the National Aeronautics and Space Administration, the Office of Naval Research, the Air Force Systems Command, the Naval Material Command, and the Army Research Office also support research in robotics. The Defense NATO Network Program Office carries out new team efforts on network architecture. Coordination with users and other sponsors of related research is maintained through joint programs, workshops, conferences, meetings between program managers, site visits, choice of contracting agent, and published research.

Power Source and Extra Hypervelocity Technology. The Solid Oxide Fuel Cell development is directly related to Service efforts in improving conversion efficiency of prime electric power sources. This program is coordinated directly with the Air Force Wright-Aeronautical Laboratories (AFWAL) and the Department of Energy (DOE) as the agents and close consideration is maintained with AFWAL and DOE efforts. Basic ultracapacitor technology is based upon a proprietary concept which employs mixed solid metal oxide materials and is related to concepts and techniques being evolved in the Joint Air Force Solid Oxide Fuel Cell development. Significant new military opportunities for high altitude air vehicles may be possible through the synergistic applications of advanced high power density fuel cells and emerging solar cell technologies. In the Extra Hypervelocity Technology program, the current effort is to explore velocity regimes and investigate the important military consequences of extra hypervelocity techniques, particularly with regard to armor defeat and materials modification.

Target Penetration Research. Armor/anti armor research is coordinated with the Army and Navy via annual joint program reviews.

Geophysical Sciences. Complementary research is conducted by the National Laboratories of the Department of Energy. The topics of seismic wave propagation and of earthquake source mechanisms are also of fundamental scientific interest and are of importance for earthquake hazard reduction. For these reasons research on these topics is also supported by the National Science Foundation and by the Nuclear Regulatory Commission. Coordination on DARPA's effort with these agencies to avoid duplication is

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accomplished by formal meetings between agencies and by the National Academy of Sciences Committees on Geophysics and Seismology.

## F. WORK PERFORMED BY:

Materials Sciences. Effort is distributed among performers as follows: 55% industry, 21% universities, 13% in-house government laboratories and 11% federally funded research development centers. The major performers include: GTE Sylvia, Towanda, Pennsylvania; Dow Chemical Company, Walnut Creek, California; Rockwell Science Center, Thousand Oaks, California; BDM Corporation, McLean, Virginia; Lanxide Corporation, Newark, Delaware; Babcock and Wilcox, Lynchburg, Virginia; Hughes Aircraft Company, El Segundo, California; University of Michigan, Ann Arbor, Michigan; University of Massachusetts, Amherst, Massachusetts; Massachusetts Institute of Technology, Cambridge, Massachusetts; Michigan State University, East Lansing, Michigan; and Virginia Polytechnic Institute, Blacksburg, Virginia. In-house laboratory efforts are performed at the Naval Research Laboratory, Washington, D.C.; Air Force Wright Aeronautical Laboratories/ Materials Laboratory, Dayton, Ohio; the National Bureau of Standards, Gaithersburg, Maryland.

Electronic Sciences. Approximately 38% of this work is performed by industry 61% by universities, and 1% by government laboratories. The top industrial performers include: Rockwell International Science Center, Thousand Oaks, California; Texas Instruments, Dallas, Texas; and Santa Barbara Research Center, Santa Barbara, California. The top university performers are: Stanford University, Stanford, California; Massachusetts Institute of Technology, Cambridge, Massachusetts; University of California, both Berkeley, California and San Diego, California; and the University of Southern California, Los Angeles, California. In-house performers are the Naval Research Laboratory, Washington, D.C., and Naval Ocean Systems Center, San Diego, California.

Systems Sciences. Approximately 55% of the work is performed by university, 36% by industry, and 9% by in-house laboratory. Major performers include: Science Applications International Corporation, Tucson, Arizona; Advanced Information and Decision Systems, Mountain View, California; Analytic Sciences Corporation, Reading, Massachusetts; TRW, San Diego, California; Ohio State University, Columbus, Ohio; the University of Wisconsin, Madison, Wisconsin; the Massachusetts Institute of Technology, Cambridge, Massachusetts; Stanford University, Stanford, California; the University of Utah, Salt Lake City, Utah; California Institute of Technology, Pasadena, California; and the Environmental Research Institute of

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Michigan, Ann Arbor, Michigan. The in-house effort is performed by the Naval Research Laboratory, Washington, D.C.

Computer and Communications Sciences. 81% university, 11% industry, and 8% in-house. The major performers are Bolt, Beranek, and Newman, Cambridge, Massachusetts; California Institute of Technology, Pasadena, California; Carnegie-Mellon University, Pittsburgh, Pennsylvania; Columbia University, New York City, New York; Massachusetts Institute of Technology, Cambridge, Massachusetts; MIT Lincoln Laboratory, Lexington, Massachusetts; Stanford University, Stanford, California; University of California, Berkeley, California; University of California, Los Angeles, California; University of Maryland, College Park, Maryland; University of Rochester, Rochester, New York; University of Southern California, Information Sciences Institute, Marina Del Rey, California; and Yale University, New Haven, Connecticut.

Power Source and Extra Hypervelocity Technology. Effort on the Solid Oxide Cell is distributed as follows: 83% is provided to a national laboratory and 17% is industry. The major performer is Argonne National Laboratory, Argonne, Illinois. Industry provides 100% of the ultracapacitor effort. The prime contractor is the BDM Corporation, McLean, Virginia. The Extra Hypervelocity Technology program is distributed 70% industry, 20% universities and 10% in-house government. Major performers are Science Applications International Corporation, LaJolla, California; Los Alamos National Laboratory, Los Alamos, New Mexico; and the Army Armament Research and Development Center, Dover, New Jersey. Industry competitions are in progress for the FY 1986 support.

Target Penetration Research. Approximately 85% of this work is performed by industry and 15% by universities. Top performers include: GTE Products, Towanda, Pennsylvania; SRI International, Menlo Park, California; and University of Washington, Seattle, Washington.

Geophysical Sciences. All of this work is performed by universities. Top performers include: University of California, Berkeley, California; California Institute of Technology, Pasadena, California; Massachusetts Institute of Technology, Cambridge, Massachusetts; Pennsylvania State University, University Park, Pennsylvania; St. Louis University, St. Louis, Missouri; and University of Southern California, Los Angeles, California.

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G. PROJECTS LESS THAN \$7 MILLION IN FY 1987:

Power Source and Extra Hypervelocity Technology. The Monolithic Solid Oxide Fuel Cell is potentially the largest single advance in direct chemical to electric energy conversion yet achieved. By utilizing a major innovation of an ion-conducting ceramic electrolyte and electron-conducting ceramic electrode and cell interconnects it appears possible to convert gasified fossil fuels directly to electrical energy at efficiencies over sixty percent. In addition, through advances in the technology of sub-miniaturized ceramic and component fabrication it now appears possible to produce an extremely compact power unit with energy and power densities exceeding those of gas turbines.

The ultracapacitor concept was demonstrated under laboratory conditions during FY 1985. Also during FY 1985 engineering parametric studies, technical and economic analyses, materials research and capacitor subscale module characterization and fabrication were conducted. Experimental modules were also tested in FY 1985. Power densities exceeded goals; however, energy density was lower than the goals. Intense effort is now underway to vary materials composition in such a manner as to permit a better balance between energy and power density. In FY 1986 a major system preliminary design for a 200 KW system will be conducted. The Ultracapacitor Development program to completion includes completion of subscale module testing and design review of the 200 KW capacitor. Pending successful design review, a detailed design, fabrication and operational evaluation of a prototype 200 KW module will be conducted which provides energy and power densities suitable for airborne weapon applications.

Additional experiments to verify these results are continuing. During FY 1986, the emphasis in this program has shifted to the extra hypervelocity regime. The primary objective is to develop the enabling technologies for extremely high velocity launchers and to explore impact physics at pressure and energy density levels. Initial development of launcher technology will be undertaken in FY 1986. During FY 1987 and out, experimental launchers will be fabricated and impact physics experiments will be undertaken.

Geophysical Sciences. In FY 1985 a large scale seismic tomographic analysis of earth structure determined detailed information on heterogeneous variations of seismic velocity within the earth. Research to use this information should lead to more accurate locations of seismic events in a monitoring context. The improved earth structure should also lead to more accurate yield estimates by means of magnitude from long-period Rayleigh waves. By use of improved instrumentation it was found that high-frequency noise levels at quiet sites are much lower than was thought here-to-fore. This implied that decoupled explosions

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could perhaps be detected at lower yields than previously thought possible. Methods to utilize additional information in the seismic signals from explosions for independent estimates of yield have been developed, and methods have been developed to isolate explosion signals from triggered earthquakes. This has important implications for improving the verifiability of a Threshold Test Ban Treaty and for the methods which should be used to estimate precise yields. In FY 1986 the tomographic research is being completed in order to better outline the 3-dimensional structure of the earth and to gain the location and yield-estimation benefits discussed above. Research is being funded to outline the geographical distribution of low noise sites; and to understand the source of the existing noise. These tasks should help predict the locations of low noise sites. Patterns in body waves are being studied to understand the cause of the patterns: propagation through varying earth structure or release of tectonic strain. Analysis and evaluation of the tectonic strain release which affects surface wave yield estimates is underway using long-period body waves. This research has given additional confidence in propagation bias estimates between Soviet and U.S. test sites. Close-in monitoring of underground tests at the Nevada Test Site and laboratory modelling experiments are helping to resolve issues of non-linear propagation under moderate strain. Earthquakes are being monitored at close distances to see if their source spectra have significant differences from those of explosions. Theories of complex earthquakes are being developed. Such earthquakes may have source spectra similar to those of explosions. Theoretical approaches to 3-dimensional scattering and propagation are being developed to compare to model studies and to finite difference calculations. These studies are of importance in developing regional discriminants which are the only discriminants which may be used for weak decoupled explosions.

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H. PROJECTS OVER \$7 MILLION IN FY 1987:

1. Project Description: The objectives are to explore new materials concepts, and seek solutions to problems which require specially tailored materials such as amorphous metals, metal matrix and ceramic matrix composites, high temperature polymers and adhesives, easily processed ceramics, materials resistant to laser irradiation, solid lubricants for ceramics, thin films, polymers, and engineered materials with enhanced nonlinear optical properties. The full exploitation of rapid solidification powder technology will make possible a 100°C increase in operating temperature limits for turbine-blades, hence higher specific thrust and lower specific fuel consumption for advanced cruise missile and tactical aircraft engines. New aluminum alloys emerging from this technology will challenge higher-cost titanium alloys and composite materials for achieving weight, cost, and fuel reductions in advanced aircraft and missiles. Metal-matrix composite research is addressing new fabrication technologies for achieving high stiffness and high strength structural alloys for use at elevated temperatures and new methods combining the advantages of rapid solidification metallurgy with metal matrix composite technology. New techniques in polymer, polymer composite and adhesive processing, including electromagnetic processing, will lead to lightweight structures designed for longer life at higher temperature. Potential DoD applications include structural members and coatings for high performance aircraft and composite structures for space. Novel ceramic processing approaches including explosive compaction and chemical synthesis techniques to produce low cost, reliable ceramics and ceramic matrix composites for structural and optical applications are being evaluated. A program to harden materials against shock waves induced by pulsed lasers will develop new composites to mitigate the effects of shocks by energy dissipation via microstructural control. Research in the fundamentals of solid lubrication of ceramics is providing options for lubrication of high temperature engines and satellites where conventional approaches cannot be employed. Processing routes for polymers and ceramics using electromagnetic energy (e.g. microwaves) are being investigated. Research is being conducted on the processing and properties of advanced intermetallic alloys for hot propulsion and airframe structures with unusually high temperature requirements (up to 1800°C). The development of a new class of polymeric composite, "molecular composites", is being undertaken, which will provide high modulus, strength and temperature and chemical stability at temperatures in excess of 450°C. Efforts are also examining the behavior of materials subjected to

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high strain rates such as in ballistic impact. The development of materials with enhanced nonlinear optical properties will reduce the susceptibility of battlefield optical sensors such as eyes, FLIR's, day and night sights and image intensifiers to spoofing, jamming and damage by low power, in band laser threats.

2. Program Accomplishments and Future Programs:

a. FY 1985 Accomplishments: Significant advances were made in materials research efforts covering a wide range of materials systems including metals, ceramics, polymers, and composites. Significant advances this year have been made in ceramics research. In explosive compaction the high temperatures and pressures remain for only milliseconds. Thus, this technique was proven to be very powerful for the forming of compositions that would be impossible using conventional ceramic processing. This may be especially important as a low cost approach to producing high performance ceramic armor. In addition, a major breakthrough has been made in Lanxide technology. Research on this proprietary process which can make ceramics and ceramic composites with unique compositions and to net shape showed the process to be even more versatile than originally thought. Plasma chemical synthesis techniques to produce ceramic powders demonstrated the capability to produce high purity aluminum nitride.

In the polymer blends research, several promising high strength polymer systems were selected and synthesized. Rapid Solidification Plasma Deposition (RSPD), a plasma deposition process to directly deposit structures with rapidly solidified microstructures, was successfully applied to fabrication of improved aircraft engine nozzle seals and was transitioned directly to production evaluation in military turbine engines. Supersteels which exhibit exceptional high temperature stress-rupture capabilities were demonstrated via rapid solidification processing and transitioned to naval air propulsion systems technology programs. In the program on rapid solidification, new higher strength and toughness weldable aluminum alloys were developed which offer significant weight reduction in future ship structure concepts, potentially providing naval vehicles with much greater speed and range, larger payload, and greater firepower.

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Significant reduction of the threshold for optical switching/limiting for protection of electro-optical sensors was demonstrated in various materials, including liquid crystals and semiconductors used in power and energy limiting applications, semiconductor charge injection switches, and free carrier absorption devices; research programs in other promising nonlinear optical materials concepts for optical sensor protection were initiated.

A comprehensive state-of-the-art review by leading experts in the field of material modelling and large-scale computer code development was conducted. Results were used to guide future programs designed to predict the behavior of materials under very high strain rates.

b. FY 1986 Program: The strong effort on ceramics research continues. The work on explosive compaction of ceramics is ending this year with a demonstration that compositions, shapes and densities suitable for armor applications can be made. This program is being transitioned to DARPA and Army armor development efforts. The exploratory phase of the Lanxide program is continuing with efforts to understand the process mechanism and to evaluate the potential of the process for DoD applications such as armor and radar absorbing materials. The compositional breakthrough discovered last year is being examined. In the effort to form single crystal sapphire IR domes to net shape the research is focussing on the development of concepts for the control of the shape. Optical and physical properties of the crystals formed via this process also are being examined. The program to demonstrate the use of supercritical fluids in the densification of ceramic and carbon-carbon composites is proceeding with the identification of polymer compositions amenable to infiltration into the composite structure. Finally, a new effort is beginning which will develop a basic understanding of the fracture behavior of ceramic composites. The first step in this effort will be to model the behavior of these materials during the fracture process.

The theoretical and experimental approaches to the blending of polymers is continuing. Promising polymers combinations are being blended based on theoretical predictions of optimum conditions and the physical properties of the resulting polymer systems are being measured. A new program is aimed at establishing novel chemical, mechanical, and evaluation approaches for improved high temperature polymeric adhesives. The goal of this effort is synthesis of adhesives capable of withstanding 370°C

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with extended service life. Another new effort is examining the use of electromagnetic energy (e.g. microwaves) for the processing or synthesis of unique polymers. The new effort in molecular composites for new classes of high temperature, high strength polymers is investigating scale-up of processing of specific chemistries and the possibility of reinforcement of these polymers by rigid rod molecular structures of identical chemistry.

The effort on rapid solidification of depleted uranium alloys is focusing on alloying for improved hardenability and armor penetration, and more homogeneous, tailored microstructures for improved post melt processing. The effort on weldable marine structural alloys focuses on weld zone morphology control and in improving alloying concepts to make more rapidly solidified aluminum alloys weldable, especially the improved modulus aluminum-lithium alloys.

A new program is being initiated in advanced intermetallic alloys for use in new metal matrix composites which have both high specific strength and modulus, and are stable at temperatures up to 1800°C for application in extremely high velocity air vehicle structures. The first phase of this effort is focussing on metal alloying concepts and processing science for high strength combined with increased ductility. Recent advances have indicated directions to dramatically improve the ductility of these inherently brittle alloys in order that they may be formed into useful shapes.

The effort to develop improved mathematical constitutive models for use in large-scale computer simulation programs is being expanded, with new work concentrating on studies of materials behavior at high strain rates and the micromechanics of deformation.

The shock hardened materials development program will examine shock mitigation in materials by fundamental experiments and correlated theory. Pulsed laser initiated shock waves will be studied by means of special diagnostics which afford an instantaneous view of the material during shock passage. Theoretical development will attempt a microstructural description of shock passage and attenuation.

c. FY 1987 Planned Program and Basis for FY 1987 Request: The efforts in ceramics research will continue to explore novel routes to the processing of ceramics and ceramic composites. Lanxide technology

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will be expanded to include a more in depth examination of the capabilities of this unique process. The program on the formation of IR domes to net shape will be completed with the demonstration that three inch domes of optical quality single crystal sapphire can be made at a cost competitive with current domes made of an inferior ceramic composition, magnesium fluoride. The use of supercritical fluids in the processing of ceramic and carbon-carbon composites will continue. The modelling effort to understand the fracture behavior of ceramic composites will be expanded with experimental work on ceramic composite samples produced in other DARPA and DoD programs.

The program to examine the fundamentals of solid lubrication of ceramics, delayed due to procurement difficulties, will begin. The first priority of this program is to establish the fundamental mechanisms of the lubrication process. New testing and surface analytical techniques will be employed.

In the high temperature polymers and adhesives program, the effort on polymer alloying via blending for co-polymeric systems will establish the basis for new polymers and composites which have thermal stability at 400-500°C. The processing routes will be transitioned to service programs for improved polymers for missile, air and land warfare structures. New adhesive systems with order-of-magnitude lifetime improvement in severe environments will be formulated for bonding of titanium and advanced composites.

The technology for future manufacture of molecular composites based on the efforts in the high temperature polymers program will be established via a joint DARPA/Air Force activity. This effort will serve as the basis for new technology base programs in the Services for improved polymeric composites which have stability in applications above 400°C.

Metal matrix composite research will emphasize refractory and intermetallic alloys for the matrix phase, and study the deformation and fracture mechanisms of these materials to develop a rationale for design of these low ductility metal matrix composites. In the effort on electromagnetic processing of materials, methods for processing both organic polyimide composites and structural ceramics and ceramic composites will be studied. These materials have the potential for high performance capability without the performance penalties associated with traditional processing routes for these materials.

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In examining shock propagation and mitigation in composite structures, an energy budget description will be achieved which shows energy distribution within the dissipation modes. Improved diagnostics will provide a practical basis to examine microstructural models to determine their validity. The effort to develop improved constitutive models for use in large scale computer simulation will continue with model development and validation work aimed at understanding the response of materials to high rates of deformation.

d. Program to Completion: The feasibility of novel concepts for ceramic and ceramic composite fabrication will be determined and those that are promising will be transitioned to exploratory development programs. Advanced ceramic and solid lubrication formulations will be evaluated and transitioned to development programs for bearings, seals, etc.. Research on high temperature polymers, high temperature adhesives, and electromagnetic energy processing will continue, with emphasis on developing fundamental knowledge leading to improved materials for military systems. Studies on metal-matrix composites will continue with a goal of producing high temperature, strong, tough, lightweight structural components for airframes, missiles and space applications. Rapid solidification research will be concluded during FY 1987 with numerous important service transitions and military applications having been realized over the course of the program.

## e. Milestones:

<u>Last Year's Reported Plan</u>	<u>Current Plan</u>	<u>Milestones</u>
Early FY 1985	Mid FY 1986	Demonstration of rapidly solidified metal matrix composite powder technology.
--	Late FY 1986	Determination of mechanism of fiber failure in pulsed laser irradiated composites under mechanical loading conditions.

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 Title: Defense Research Sciences  
 Budget Activity: 1. Technology Base

<u>Last Year's Reported Plan</u>	<u>Current Plan</u>	<u>Milestones</u>
--	Late FY 1986	Demonstrate alloys for advanced kinetic energy penetrators based on rapid solidification.
Late FY 1986	Late FY 1986	Weldability of rapidly solidified aluminum alloys demonstrated.
Late FY 1986	Late FY 1986	Demonstrate blended polymer system with optimum physical and chemical properties.
--	Early FY 1987	Demonstration of applicability of constitutive mechanics models to predict behavior of materials under high rates of loading.
--	Late FY 1987	Demonstrate processing capability for molecular composites with optimum mechanical properties.
--	Late FY 1987	Determination of energy budget for pulsed laser effects on composite material.
--	Early FY 1988	An assessment of the advantage of Lanxide ceramic technology in a variety of DoD applications will be completed.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: MS-1  
 Program Element: #61101E  
 USDR&E Mission Area: 530

Title: Materials Sciences  
 Title: Defense Research Sciences  
 Budget Activity: 1. Technology Base

Last Year's  
 Reported Plan

Current  
 Plan

Milestones

Late FY 1988

Approaches for the solid lubrication of ceramics at both high (1650°C) and low (-5°C) temperatures will be established.

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f. Explanation of Milestones Changes: The project on rapid solidification of metal-matrix composites experienced technical difficulties as a result of a chemical reaction between the aluminum matrix and the reinforcing ceramic-silicon carbide. The project was redirected to replace the silicon carbide with titanium diboride.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: #ES-1  
Program Element: #61101E  
USDR&E Mission Area: 530

Title: Electronic Sciences  
Title: Defense Research Sciences  
Budget Activity: 1. Technology Base

H. PROJECTS OVER \$7 MILLION IN FY 1987:

1. Project Description: The objective of this project is to explore and demonstrate device, material, and material processing concepts which will provide: (1) new technical options for implementation of future electronic and optical systems and functions for information transmission, gathering and processing; and (2) substantial increases in performance, survivability, reliability, and availability of electronic components and monolithic, high functional throughput circuits at reduced cost per function. Specific areas of electronic and optical materials device and manufacturing research include revolutionary new approaches to produce large area infrared sensor materials and devices for strategic and tactical systems; innovative processes, device design concepts, and computer-based process design aids for submicron feature size integrated circuits; compound semiconductors; electronic and optically active polymers; monomolecular thin film structures; photorefractive materials and device development for achieving spatial light modulators; and nonlinear optical effects for analog and digital optical computing.

2. Program Accomplishments and Future Programs:

a. FY 1985 Accomplishments: Residual p-type impurities in bulk mercury cadmium telluride (MCT) were reduced by a factor of 3 to 5 and MCT surface passivation coatings comparable in quality to those used in silicon Metal Oxide Semiconductor integrated circuits were achieved. These advances make possible the development of MCT arrays which monolithically combine detectors and signal processing circuits.

High quality layers of MCT were grown on gallium arsenide substrates by both molecular beam epitaxy (MBE) and metal organic chemical vapor deposition (MOCVD). Preliminary data on MBE layers of mercury zinc telluride (MZT) indicated that, as predicted by theory, the mechanical and electro-optical properties of MZT are significantly superior to those of MCT. Photovoltaic detectors were fabricated in bulk mercury manganese telluride and epitaxial mercury cadmium manganese telluride with electro-optical characteristics similar to good quality MCT detectors.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: #ES-1  
Program Element: #61101E  
USDR&E Mission Area: 530

Title: Electronic Sciences  
Title: Defense Research Sciences  
Budget Activity: 1. Technology Base

Superlattices in a variety of II-VI materials were grown and characterized, and stimulated emission in the red was observed from cadmium manganese telluride and cadmium telluride multiple quantum well structures.

A major breakthrough in reproducible processing of the millimeter wave Permeable Base Transistor (PBT) was achieved through the application of metal organic chemical vapor deposition (MOCVD). Measurements indicated that PBT's capable of operation at frequencies above 100 gigahertz could be fabricated reproducibly .

Velocity overshoot was directly measured by optical techniques in a gallium arsenide device. Exploitation of this effect will improve high frequency performance of mm wave transistors.

First generation gallium arsenide (GaAs) integrated circuit technology research was transferred to Strategic Defense Initiative Organization (SDIO) funding and silicon process modeling research began transfer to the Very High Speed Integrative Circuit (VHSIC) program office.

The research on organic nonlinear optical materials led to the discovery of a disubstituted diphenyl acetylene compound which exhibits the highest third order nonlinearity ever reported for a polymeric material. Furthermore, a new computer assisted molecular modelling scheme was implemented, and it has led to the identification of a molecular structure which is predicted to have a nonlinearity about two orders of magnitude greater than the above mentioned acetylene compound.

University and industry researchers combined to demonstrate a new application of direct writing with a laser beam. The experiment used an ultraviolet laser to correct a metal interconnect design error on a working, but imperfect, large scale integrated circuit chip, and thereby verified the circuits' performance without a second time consuming and costly design and prototype fabrication cycle.

Remarkable images of the surface of graphite were produced using the scanning tunneling microscope (STM). Operating in air at ambient temperature, the ultra-high resolution tunneling microscope exhibited

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: #ES-1  
Program Element: #61101E  
USDR&E Mission Area: 530

Title: Electronic Sciences  
Title: Defense Research Sciences  
Budget Activity: 1. Technology Base

the capability of reproducibly imaging the surface of a graphite sample at a resolution of smaller than 2 angstroms (atomic dimensions).

A major milestone was reached in the development of device quality Langmuir-Blodgett (LB) thin films. Insulated-gate field-effect transistors (IGFETs) were successfully fabricated on silicon wafers using LB films as gate dielectric layers.

b. FY 1986 Program: Materials and device efforts directed towards achieving millimeter wave, three terminal devices are continuing. Emphasis is placed on utilization of velocity overshoot to achieve the carrier velocities required to realize such devices. Specific device structures under investigation include the Permeable Base Transistor (PBT), Vertical Field Effect Transistor, Ballistic Injection and Drift Transistor, the Opposed Gate-Source Transistor (OGST), the heterojunction bipolar transistor (HJBT) and tunneling structures.

Research on growth and processing of large area mercury cadmium telluride (MCT) and other II-VI infrared sensor materials is continuing with emphasis on the molecular beam epitaxy (MBE) method. Investigation of depositing device quality layers on dissimilar substrates will continue. A selection is being made between the use of CT or other materials for large area substrates for epitaxial growth of MCT for manufacturing purposes. Infrared detector and multi-layer superlattice devices of CT, MT, MCT, Mercury Zinc Telluride (MZT) and other II-VI alloys are being prepared and evaluated. These layered structures are prepared by MBE and metal-organic chemical vapor deposition (MO-CVD). Research on the growth of the dilute magnetic semiconductor manganese telluride (MMT) and related compounds to study and exploit their infrared (IR) and magnetic properties is being expanded. The feasibility of utilizing wide bandgap MCT for fabricating high speed optoelectronic devices capable of near IR operation is being explored. Work on the monolithic integration of MCT detectors and signal processing circuitry is being initiated.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: #ES-1  
Program Element: #61101E  
USDR&E Mission Area: 530

Title: Electronic Sciences  
Title: Defense Research Sciences  
Budget Activity: 1. Technology Base

Materials and device research programs are being initiated to develop laser source and detector technology for optical satellite communications. This involves the use of MBE and/or MOCVD to fabricate novel heterojunction devices and monolithic optoelectronic circuits in the III-V semiconductor materials.

The program to fabricate two-dimensional spatial light modulators (SLMs) is constructing the first prototype of a deformable membrane modulator which is frame-addressable rather than just line-addressable. Fabrication is beginning on another SLM, based on silicon deposited on an electro-optic ceramic, which has the potential for a framing rate of 1 megahertz.

The optical materials program, to create improved photorefractive materials for light modulation and nonlinear materials for optical switching, is continuing to expand. Organic polymeric materials are being incorporated into device structures to determine operating characteristics. Increased emphasis is being placed on the nonlinear optical characterization, especially the third order susceptibility, of both the inorganic insulator materials and the organic polymeric materials.

Work is being initiated on optical processing architectures and algorithms capable of dealing with symbolic manipulations in addition to the standard numeric computations. The inherent power of optics to perform two-dimensional correlations and to facilitate interconnects between processing elements is being investigated for its potential for enhancing such symbolic operations as searching, matching, and sorting.

In support of all the above activities, new analytic instrumentation programs are being initiated. New optical techniques for characterizing band structure, transport properties and high frequency performance of semiconductor structures are beginning development. Direct measurements of device properties up to 100 gigahertz are being attempted.

c. FY 1987 Planned Program and Basis for FY 1987 Request: Device designs that have yielded successful demonstrations of millimeter-wave operation will be directed towards monolithic implementations that contain both the active and passive devices needed for monolithic mm-wave phased

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: #ES-1  
Program Element: #61101E  
USDR&E Mission Area: 530

Title: Electronic Sciences  
Title: Defense Research Sciences  
Budget Activity: 1. Technology Base

array modules. Monomolecular Langmuir-Blodgett films will be applied to novel materials and device structures to evaluate the passivation potential of these films. High vacuum, in-situ fabrication of submicrometer integrated circuits by combining various beam processing concepts in one interconnected system will be continued. Molecular Beam Epitaxy (MBE) and Metal Organic - Chemical Vapor Deposition (MO-CVD) research will be directed towards device fabrication to verify the improvements in uniformity of response and detection efficiency that is expected from materials grown by these advanced techniques. New device concepts, that exploit the magnetic properties of novel semiconductors such as mercury manganese telluride, will be explored. Successful mercury cadmium telluride/substrate materials combinations will be advanced toward demonstration of a large pixel focal plane. Other candidate infrared imaging large focal plane technologies will be evaluated in parallel.

The Research effort in superlattices will be expanded. The developments of molecular beam epitaxy (MBE) and metal-organic chemical vapor deposition (MO-CVD) systems have opened up a totally novel concept for semiconductor technologies-materials engineering. Artificially created superlattices can, in principle, be tailored to yield pre-determined bandstructures selected to optimize device performance. Essentially a multi-dimensional materials space has been opened up with near infinite combinational possibilities that will significantly expand the capabilities of future electronic and optical devices. Initial efforts in the development of superlattices have revealed a lack in both theoretical understanding and experimental techniques. This program will combine theorists with established experimental groups to define optimum research directions and resolve present uncertainties in predictive capabilities. In addition device related research will involve heterojunction bipolar transistors (HBT), high electron mobility transistors (HEMT), and tunable optical components.

Continuing efforts will include: Processing technology for submicrometer feature sized digital and analog circuits; three terminal device research for millimeter-wave amplifiers; growth and characterization of narrow bandgap materials and research into MOCVD-and MBE-based devices for infrared focal plane arrays, exploration of electronic and optical polymers for unique properties of significance to DoD applications, and optical techniques for symbolic computing.

# FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: #ES-1  
 Program Element: #61101E  
 USDR&E Mission Area: 530

Title: Electronic Sciences  
 Title: Defense Research Sciences  
 Budget Activity: 1. Technology Base

Research will be directed toward enhancing the interfaces between optical and digital systems, with a focus on improving architectural linkages, identifying the appropriate electronic/optical conversion points for various problem domains, and concurrently developing algorithms with data representations for optical processing which are more compatible at the output with digital formats. This research will be directed toward alleviating a mounting problem for optical processors, that of converting inputs from digital streams to optical data and restoring digital compatibility at the output.

d. Program to Completion: Research efforts exploring the feasibility of specific new concepts in devices and materials within the Electronic Sciences Project generally have a duration of three to six years. New efforts will be expanded in technology applications of monomolecular films, superlattices, electronic polymers, and three dimensional circuit structures. Exploration of revolutionary in-situ, high vacuum integrated circuit fabrication will be required to keep the lead in electronics from evaporating since conventional processing technology cannot be pushed in an evolutionary manner to tenth micrometer dimensions. Exploration of magnetic semiconductors will expand. The submicron materials and device physics effort will continue in FY 1988 and beyond due to the far-reaching operational significance which accompanies success, and the extreme technical challenge involved. Efforts in extremely high frequency device and material structures will continue beyond FY 1988 due to their emerging importance in super-computation, and secure communications as well as electronic warfare (EW).

e. Milestones: The milestones reported in the FY 1986 Descriptive Summary have been completed or are expected to be completed on schedule except as noted below:

Last Year's Reported Plan	Current Plan	Milestones
Late FY 1985	Mid FY 1986	Successful fabrication and demonstration of high speed two-dimensional spatial light modulation.

# FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: #ES-1  
Program Element: #61101E  
USDR&E Mission Area: 530

Title: Electronic Sciences  
Title: Defense Research Sciences  
Budget Activity: 1. Technology Base

<u>Last Year's Reported Plan</u>	<u>Current Plan</u>	<u>Milestones</u>
--	Late FY 1986	Demonstration of reproducible p-n junctions in MCT by in-situ MBE techniques.
Mid FY 1986	Mid FY 1986	Evaluation of particle count in vacuum processing environment.
Mid FY 1987	Mid FY 1987	Demonstration of useful gain and power at 60 GHz from GaAs heterojunction bipolar device.
Mid FY 1987	Mid FY 1987	Demonstration of the compatibility of all necessary beam processing techniques for complete device fabrication.
New	Early FY 1988	Demonstration of device quality polymeric alloys for low power, electro-optic devices.
New	End FY 1988	Completed evaluation of alternative mercury telluride systems for improved infrared detecting material systems vis-a-vis mercury cadmium telluride.

f. Explanation of Milestone Changes: The spatial light modulator demonstration was delayed due to an unfortunate fabrication error.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: DRH-1  
Program Element: #61101E  
USDR&E Mission Area: 530

Title: System Sciences  
Title: Defense Research Sciences  
Budget Activity: 1. Technology Base

H. PROJECTS OVER \$7 MILLION IN FY 1987:

1. Project Description: The goal of this project is to develop the systems sciences that form the basis for technological aids to augment the performance of Department of Defense personnel. Problems that have been addressed include: distributed group decision making and group communication; analysis of imagery data; design of control systems for adaptive suspension and other complex vehicles; and the development of advanced bio-chemical technology to allow large scale production of biological materials and structures with novel physical and chemical properties leading to the enhanced performance of man-made devices and systems.

One technical initiative is in command and control information systems. This effort involves: development of a "perceptually interactive" system for the commander to query his information data base; the development of heuristic, analytic and electronic techniques to aid in the increasing problem of high resolution synthetic aperture radar image exploitation; and the development of an inexpensive tethered reconnaissance platform with an extremely light weight imaging and motion detecting radar to provide the front line commander with the ability to "see over the next hill."

A second effort is in the area of adaptive vehicle technology. This research will provide new controls and capabilities for land-based travel over previously inaccessible terrain using a new control system that anticipates the future path using a laser terrain mapper, relieves the operator of responding to the details of that terrain, and adapts the suspension of the land based vehicle to accommodate to the terrain. Preliminary data to date demonstrates major mobility improvements, e.g., a doubling of maximum speed of travel over rough terrain.

Another initiative develops and exploits the area of advanced biochemical technology. This effort involves: the synthesis of biological materials and structures and the characterization of their novel physical and chemical properties; the solution of problems central to large-scale material production and processing; and the structural and functional integration of unconventional materials and components in device and system applications. Applications include the development of ultra-sensitive and

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: DRH-1

Program Element: #61101F

USDR&E Mission Area: 530

Title: System Sciences

Title: Defense Research Sciences

Budget Activity: 1. Technology Base

ultraspecific strategic and tactical chemical sensors; the in-situ synthesis and exploitation of novel biopolymers for enhanced submarine speed, stealth, and (acoustic) sensor performance; the development of advanced neural-analog computer architectures and high density, fault-tolerant, content-addressable information storage devices; the production of novel micron/sub-micron scale self-organizing, polymerizable lipid structures for diverse optical, electromagnetic, and mechanical systems applications; the production of specialty adhesives; the development of surfactant and polymeric materials for enhanced ocean surveillance; the synthesis of novel electronic materials; and the fabrication of molecular electronic/electro-optical devices and structures.

2. Program Accomplishments and Future Programs:

a. FY 1985 Accomplishments: In the area of adaptive platforms for land-based travel, the fabrication of a full-scale hexapod vehicle was completed. This vehicle will weigh 2,268 kilograms, stand 2.13 meters high and is 4.27 meters in length. It will be capable of moving over rough terrain, non-negotiable by conventional wheeled or tracked vehicles at a speed of 13 kilometers per hour. It will go up 75% slopes, cross-slope on a 75% grade, climb over 1.83 meter high obstacles, and cross 2.13 meter wide ditches. The completed vehicle was tested in the precision footing made using onboard primary power and onboard computers. The work on a dynamically balanced quadraped was extended to include galloping and trotting. A turbine/flywheel system was completed as an alternative prime mover/storage system for the hexapod. Design studies for a full-scale autonomous quadraped were initiated.

As an aid to the analysis of high resolution synthetic aperture radar imagery, initial prototypes of subsystems for vehicle detection, vehicle classification, contextual and collateral analysis, and force structure analysis were demonstrated. A prototype of a tethered ducted fan platform for elevated reconnaissance was demonstrated. The platform supported a video camera link to elevations of 200 feet.

Work in biochemical technology put emphasis on material synthesis, characterization, and early system design and evaluation. Significant accomplishments include the development of controlled, target-mediated, liposome lysis/optical signal generation systems; demonstration of rapid assays for the typhus

# FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: DRH-1

Program Element: #61101E

USDR&E Mission Area: 530

Title: System Sciences

Title: Defense Research Sciences

Budget Activity: J. Technology Base

surface protein antigen; demonstration of rapid, simple, and superior methods for determination of serum-complement levels; the development of novel hyperstable enzymes; the achievement of a 100-fold increase in release tag operating speed; the development of methods for the effective thermal cleaning of field-emitter tips thus preserving the operating integrity of liquid-field quantum tunneling chemical sensors; the design of monolithic solid-state electrochemical sensors compatible with advanced "receptor-based" detection concepts; the discovery of novel synthetic antibody-based catalysts, "abzymes;" the demonstration of a significant (60%) friction reducing capacity for biopolymers synthesized by diverse methylothermic, hydrogen-oxidizing, and photo-autotrophic micro-organisms; the development and experimental verification of theoretical models of the coil-stretch transition of polymers subject to extensional flow; the development of solutions to the large-scale ADAPT interconnect problem allowing fabrication of generalized adaptive distributed analog processors; the design of a full-scale ADAPT processor with 10<sup>6</sup> processing elements and 10<sup>6</sup> interconnects; the design of a VLSI-based "Hopfield" memory matrix for high density information storage; demonstration of the utility of error-correcting codes for the memory matrix -- a 500 fold increase in the information storage capacity per active element without retrieval error; demonstration that information retrieval is possible in both auto and serial associative modes; demonstration that hydrogenated amorphous silicon thin films may be used for read-only devices; and the synthesis of novel, polymerizable, self-organizing lipid structures potentially useful as broad-band electromagnetic countermeasure materials, as novel structure in liquid separation technology, as solid-phase substrates in fermentation, as novel "vectors" for the incorporation of megabase DNA into eukaryotic cells, as a natural medium for the exchange of cellular material, and as optically active elements and composite materials.

- b. FY 1986 Program: There are four major components to the FY 1986 program. First, a program to develop six testbed models of the tethered reconnaissance platform is being initiated. The thrust will be in improving system stability and control and making the prototypes available for application evaluation. Two of the platforms will support another new start which is focussed on developing a less than ten pound radar payload which when combined with the tethered platform will give the Services an inexpensive means to image and detect motion out to ten kilometers in all weather and day-night conditions.

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Project: DRH-1

Program Element: #6J101F

USDR&E Mission Area: 530

Title: System Sciences

Title: Defense Research Sciences

Budget Activity: 1. Technology Base

Second, the indoor and outdoor walking tests of the hexapod vehicle are being completed and evaluated. This approach makes possible new tactics and all weather operation now precluded and is designed to ease inventory problems (many different vehicles for many different missions) and training problems experienced by military personnel. Work is starting on an artificial intelligence based navigation system which is necessary in order for the walking machine to operate autonomously. Animate Systems research is being initiated in order to understand the control of cooperative behavior for groups of vehicles. Software for the following modes of operation is being developed for the walking machine: close maneuvering, cruise, dash, and terrain following.

Third, advanced chemical sensor research is emphasizing the design of multiple assay, solid-state, and quantum sensing devices and will focus attention on problems related to the production of both natural and synthetic receptors and complex device packaging issues. Work with viscoelastic biopolymers should complete initial production yield and material characterization efforts, continue efforts to relate biopolymer structure and hydrodynamic performance, and complete phase 1 transport-limited fermenter design studies. Neural-network research emphasizes completion of phase 2 hardware efforts and demonstration of system utility against real world radar target classification problems. Work with novel biological structures is extending current means for material synthesis, exploring underlying phase transitions, and examining methods for structural modification and enhancement of electrical conductivity. Development of novel "wet" adhesives will complete phase 1 efforts exploiting recombinant DNA techniques to synthesize the base protein analogous to the marine mussel adhesive as well as efforts at post-synthetic enzymatic modification. Efforts to enhance ocean surveillance capabilities will focus on theoretical studies of the effects of polymers at the air-sea interface and direct measurements of the role of surfactants in reducing surface-generated broadband noise. Synthesis of novel electronic materials puts emphasis on the rational design of polypeptide composites exhibiting unusual pyro- and piezo-electric properties, and initiation of efforts at the direct synthesis of pleated sheet structures with pre-determined amino-acid sequences. A related, theoretical study, attempts to characterize the dynamic internal properties of biopolymers by properly accounting for fluctuation-dissipation processes in open quantum-mechanical systems to allow prediction of the stability properties, transport properties, and lifetimes of polymeric solitons as a function of temperature - key issues in the design

FY 1987 PDT&F DESCRIPTIVE SUMMARY

Project: DRH-1

Program Element: #61101F

USDR&F Mission Area: 530

Title: System Sciences

Title: Defense Research Sciences

Budget Activity: 1. Technology Base

of molecular electronic devices. With respect to device fabrication, efforts are focussed on the development of flexible, practical techniques for the assembly of structurally well characterized organic monolayer films on clean metallic, semi-conducting, and insulating substrates. These films are being formed by adsorption of precursors from solution and their spontaneous self-organization on the substrates.

Fourth, prior work in developing aids, heuristics and algorithms to aid in the analysis of high resolution synthetic aperture radar imagery is being combined in a system concept demonstration. In the latter part of FY 1986, a parallel effort to transition the technology to the Army is being initiated. The identified application is an intelligent target screener. The impact will be to remove a major bottleneck in new imagery collection systems, namely that the technology for the collection of imagery far outstrips existing capability for the manual analysis of images due to limitations in the number of military personnel with the required skills.

c. FY 1987 Planned Program and Basis for FY 1987 Request: Research will continue across a broad spectrum of innovative investigations in systems sciences, including: development, demonstration and evaluation of analytic aids for high resolution synthetic aperture radar image analysis in support of an Army intelligent tactical screener; development, demonstration and evaluation of inexpensive "over-the-next-hill" reconnaissance technologies; development, demonstration and evaluation of "perceptually interactive" display and interface technologies; several activities associated with achieving a fast, agile four legged vehicle will be initiated including the design of hydraulic components, the vehicle body, and legs. Software for autonomous operation will be transferred from the autonomous land vehicle program to the hexapod walking machine; research will continue on the control of small dynamically balanced quadruped vehicles; as will the research in the use of biological and quasi-biological materials and structures in advanced chemical sensor technology, submarine performance enhancement, advanced neural network computer architecture, high-density information storage devices, recombinant/separation/fermentation technology, specialty adhesives, enhanced ocean surveillance, novel high performance electronic materials, and the fabrication of molecular electronic and electro-optical devices.

# FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: DRH-1  
 Program Element: #61J01E  
 USDR&E Mission Area: 530

Title: System Sciences  
 Title: Defense Research Sciences  
 Budget Activity: 1. Technology Base

d. Program to Completion: Future program content will be determined by research results, technology options and operational problems arising in this critical area.

e. Milestones: The milestones reported in the FY 1986 Descriptive Summary for FY 1985 have been completed on schedule.

<u>Last Year's Reported Plan</u>	<u>Current Plan</u>	<u>Milestones</u>
Early FY 1986	1) Early FY 1986	Quadruped operated at gallop gait
Mid FY 1986	3) Mid FY 1986	Hexapod tested to design limits
--	8) Mid FY 1987	Enhanced hexapod speed via turbine/flywheel prime mover
--	2) Early FY 1986	Completion of ADAPT architecture, processor, and support software specifications
--	4) Mid FY 1986	Completion of protocol for alternative lipid tubule synthesis
--	5) Late FY 1986	Development of basic AMIS multisensor
--	5) Late FY 1986	Completion of phase 1 biopolymer hydrodynamic characterization
Mid FY 1987	9) Mid FY 1987	Demonstration of synthetic aperture radar (SAR) image analysis system
--	16) Mid FY 1989	Intelligent Target Screener Demonstration
--	10) Mid FY 1987	Elevated Tethered Reconnaissance Platform Demonstration

# FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: DRH-1  
 Program Element: #61101E  
 USDR&E Mission Area: 530

Title: System Sciences  
 Title: Defense Research Sciences  
 Budget Activity: 1. Technology Base

--	15) Late	FY 1988	Extremely Light Weight Radar Demonstration
--	13) Late	FY 1987	Autonomous operation of the hexapod
--	17) Mid	FY 1989	Full scale quadruped assembled
--	7) Early	FY 1987	Delivery of first ADAPT processor
--	11) Mid	FY 1987	Completion of fermenter transport analysis
--	12) Mid	FY 1987	Evaluation of surfactant broad-band noise suppression
--	14) Late	FY 1987	Demonstration of membrane stabilization and functional utility for solid state electrochemical systems

f. Explanation of Milestone Changes: The autonomous vehicle road following demonstration was deleted because this milestone is part of the strategic computing program.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: #CCS-2  
Program Element: #61101E  
USDR&E Mission Area: 530

Title: Advanced Digital Structures & Network Concepts  
Title: Defense Research Sciences  
Budget Activity: 1. Technology Base

H. PROJECTS OVER \$7 MILLION IN FY 1987.

1. Project Description: The objective of this project is to develop the fundamental technology in advanced digital structures and network concepts for future distributed military information processing systems. Design methodologies and computer aided design tools are being developed for Very Large Scale Integrated technology which will reduce projected design time and cost over present methods and produce designs of the quality and robustness required for DoD applications. System and Network concepts are being explored for use in future Communications, Command & Control architectures which will lead to survivable systems which are easier and faster to use than is currently possible. User interface techniques are being developed which simplify access to distributed resources and anticipate the intent of the user. Concepts for partitionable systems are being developed whereby a system can continue to function at a useable level of capability as multiple separate pieces after being split or prior to merging into an integrated system. Techniques are being developed to facilitate resource sharing among computers and provide easy construction of tailored service units by the user.

2. Program Accomplishments and Future Programs:

a. FY 1985 Accomplishments: Design capabilities for small geometry complimentary metal oxide and gallium arsenide semiconductors were developed and tested. Circuits having in excess of 100,000 transistors were designed for implementation of advanced computing architectures. Wafer level circuits having a complexity of over one million transistors were demonstrated. Advanced computer architectures implementing high level application oriented languages were investigated. Concepts for highly parallel, fine mesh machine architectures are being demonstrated. Small systems were developed and demonstrated using voice recognition to support interactive user interfaces utilizing both feature-based and template-based approaches. A distributed kernel for partitioned software systems was developed, and partitioned system operation was demonstrated. Special programs

FY 1987 RDT&E DESCRIPTIVE SUMMARY

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Program Element: #61101E  
USDR&E Mission Area: 530

Title: Advanced Digital Structures & Network Concepts  
Title: Defense Research Sciences  
Budget Activity: 1. Technology Base

called agents were developed to assist the user in using partitioned systems and in dealing with unfamiliar operating systems.

b. FY 1986 Program: Our Very Large Scale Integrated (VLSI) architecture and design efforts are aimed to develop an integrated capability for the design, fabrication, and test of integrated circuits containing in excess of a million gates. Efficient design systems for negative metal oxide, complementary metal oxide and gallium arsenide semiconductors are being demonstrated. Designs are being scaled to submicron dimensions. Innovative architectures and testing procedures for use with VLSI are being developed. Design tools are being developed to support advanced automation techniques for combined electronic and mechanical piece-part assemblies. Research in cooperative interactive systems is providing a methodology for building information services which share a natural, easy-to-use interface that is consistent across different systems. User interfaces are being developed that maintain the underlying consistency of a workstation environment while customizing that same environment for specific users using a semantic model of available functions and data. Work in combining natural language and graphic gesture presentations is beginning. Capabilities are being developed to incorporate continuous speech as an integral component of user interfaces. A visual system that reads lips without acoustic correlation is being demonstrated. A modular object oriented database management system that can be extended to meet the demands of new applications is being developed. Automated techniques for robust estimation of phoneme model parameters is being demonstrated.

c. FY 1987 Planned Program and Basis for FY 1987 Request: VLSI architecture and design efforts will address the cooperative use of design systems by large communities of designers, either in collaboration on large projects or individually in the sharing of computing resources. Design tools based on very low cost workstations will be interfaced with local area networks and the ARPANET to access centralized facilities such as design databases and hardware accelerators. Advanced computer architectures based on CMOS and GaAs technology will be used to demonstrate these new design capabilities. Research directed toward user interface technology development will develop methods for

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: #CCS-2  
Program Element: #61101E  
USDR&E Mission Area: 530

Title: Advanced Digital Structures & Network Concepts  
Title: Defense Research Sciences  
Budget Activity: 1 Technology Base

a new paradigm for computer interaction which integrates multiple channels for both input and output. Systems will be more graphically oriented and the process of reasoning about the best mode of interaction will be partially done in the software interface. Research in speech recognition will develop the means to represent the acoustic-phonetic and lexical knowledge necessary for advanced speech recognition tasks. Expert systems will be applied to the mechanical design problem. Methods to assist users in designing and developing strategies and detailed plans in an interactive way will be supported by software and concept development. Investigation into basic issues regarding the development of an extensible database management system will focus on issues of system architecture, query optimization and compilation, concurrency control, recovery, query processing, and buffer management strategies.

d. Program to Completion: This is a continuing program. Advanced silicon compiler technology will be developed and this design technology will be extended to other design disciplines. Mechanical design systems will be coupled with existing flexible manufacturing systems to demonstrate demand manufacturing of mechanical components. Emphasis will be placed on integrating total system designs to facilitate manufacture and support of total systems. Experimentation in advanced computing architectures will continue with major emphasis placed on rapid prototyping of very high performance special purpose machines. Very Large Scale Integrated architecture and design efforts will focus on development of integrated capabilities for the design, fabrication, and test of integrated circuits containing in excess of one million gates and for the rapid prototyping of systems containing circuits of this complexity. Concepts for computer aided design in electronics will be extended and applied to the mechanical design problem. Research in speech will produce connected-word speech systems that can perform simple functions such as data base retrieval and machine operating system commands. Intelligent user interfaces will combine natural language and graphic outputs, and user models that anticipate work session scenarios will be implemented. Core database functions will be implemented into an extensible architecture so that results of performance measurements can be used to improve system efficiency. Operating and network management systems will

# FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: #CCS-2  
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Title: Advanced Digital Structures & Network Concepts  
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result in robust, survivable systems that continue to provide local utility in the face of major global outages.

## e. Milestones:

<u>Last Year's Reported Plan</u>	<u>Current Plan</u>	<u>Milestone</u>
Late FY 1986	Late FY 1986	Demonstrate Gallium Arsenide design capability.
Late FY 1986	Late FY 1986	Demonstrate combined English/graphics user interface capabilities.
Late FY 1986	Late FY 1986	Demonstrate, via simulation, algorithms for data reconstitution with minimal error and minimal communications between models.
	Late FY 1986	Develop a database management system that can be extended to meet the demands of new applications in a modular fashion.
Late FY 1986	Late FY 1986	Demonstrate automated techniques for robust estimation of phoneme model parameters.

# FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: #CCS-2  
 Program Element: #61101E  
 USDR&E Mission Area: 530

Title: Advanced Digital Structures & Network Concepts  
 Title: Defense Research Sciences  
 Budget Activity: 1. Technology Base

Late FY 1986	Late FY 1986	Demonstrate demand manufacture of Integrated Circuits components based on functional specification.
Mid FY 1987	Mid FY 1987	Demonstrate new concepts of using graphics for interaction with computers along with commands and queries in order to more easily represent user intentions.
	Late FY 1987	Demonstrate a combined lip reading and acoustic speech system that can perform recognition of isolated words under varying ambient noise conditions.
Late FY 1987	Late FY 1987	Demonstrate a speaker independent recognition system for continuous digit and number recognition and continuous spelling.
End FY 1987	End FY 1987	Develop design techniques for integrated systems.
	Early FY 1988	Implement two trial database systems using an extensible database system prototype and evaluate the performance.

f. Explanation of Milestone Changes: None.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: # CCS-3  
Program Element: # 61101E  
USDRE Mission Area: 530

Title: Modernization Technology  
Title: Defense Research Sciences  
Budget Activity: 1. Technology Base

H. PROJECTS OVER \$7 MILLION IN FY 1987:

1. Project Description: This project has three primary goals: 1) to strengthen U.S. universities' ability to conduct critical fundamental research in information processing by providing, and maintaining a base of modern computing resources; 2) to develop computer techniques for advanced robotics and 3) to develop automated design techniques for application to rapid system prototyping. The modernization area was highlighted by the Defense Science Board as a critical area for investment, if the U.S. technology leadership in information processing is to be maintained. Existing equipment, which in some cases is almost twenty years old, is being upgraded from large time-sharing systems to powerful single-user workstations configured in local networks. Experimental computer resources such as symbolic processors with large address space and high resolution graphics displays are being provided to U.S. universities performing DoD research to stimulate innovation in the fields of artificial intelligence, Very Large Scale Integrated architecture, software technology, design systems, robotics, and automated manufacturing. This effort will continue through FY 1988. In the area of automated system design, ways in which information processing can close the gap between the generation of ideas and their concrete realization in the form of visual models, physical objects, or mechanical systems are being explored. These efforts will emphasize the human interface and will use advanced manipulators and display technology as appropriate. High-resolution graphics systems will be used to aid in the description of complex objects and to provide a graphical representation of objects described by information structures. Research in robotics is focused on developing automated systems that can be instructed in high-level languages and determine goals to be accomplished, then reason about and plan specific steps to meet them. To meet these objectives, highly developed perceptual and spatial reasoning systems must be integrated with mechanical effectors. Other efforts involve development of systems for describing and transforming shape, motion, and structural information, the synthesis of complex mechanical structures, and computer representation of 3-dimensional scenes which can be derived from visual, tactile or other sensor information. Design and implementation of real-time controllers for effective spatial manipulation of physical objects will be pursued and techniques explored to improve the productivity of

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: # CCS-3  
Program Element: # 61101E  
USDRE Mission Area: 530

Title: Modernization Technology  
Title: Defense Research Sciences  
Budget Activity: 1. Technology Base

scientific researchers by providing automated assistance for manual tasks which are tedious, time-consuming and error-prone.

2. Program Accomplishments and Future Programs:

a. FY 1985 Accomplishments: The computer resource modernization effort placed state-of-the-art equipment at a total of eight universities, along with appropriate maintenance. Equipment included symbolic processing machines with large address spaces and high-performance graphic capabilities, file servers, network gateways, and local network hardware. An advanced manipulator robot hand, known as the Utah/MIT hand, was demonstrated in which each of the eight tendons in its four fingers is controlled by a micro-computer. The Salisbury robot hand has been modified so that one of its fingers now has a thimble-sized, six-axis force sensor so that contact point and direction can be tactually determined. An initial set of spatial and temporal algorithms have been developed that can be used for robot planning. Autonomous robotic navigation processes which use visual information from real-time 3-D scene understanding algorithms, including stereo perception, laser ranging, and optical flow techniques have been demonstrated. Some stochastic sampling techniques for anti-aliasing have been demonstrated which prove effective in eliminating the jagged lines caused by digital sampling during design automation. Graphic animation algorithms used to model the motion of articulated bodies such as humans and robots have been improved by using dynamic analysis instead of kinematic specifications. These improvements will lead to more reality in graphic displays of defense systems in active employment.

b. FY 1986 Program: State-of-the-art computing resources are being provided and maintained at critical research laboratories. Research in robotics will be focussed on spatial and temporal reasoning in planning. The trade-offs between high level event planning using an overall time-map of possible futures (including the recent past) with the detailed planning necessary to decide the required sequence of tasks and their possible interactions will be investigated. Work in robotic

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: # CCS-3

Program Element: # 61101E

USDRE Mission Area: 530

Title: Modernization Technology  
Title: Defense Research Sciences  
Budget Activity: 1. Technology Base

control and manipulators will emphasize robotic hands using new tactile sensors and point-oriented object descriptions to recognize and manipulate objects from touch alone. In addition, languages and techniques for robotic instruction will be explored. The use of stochastic sampling techniques is being extended to image synthesis for design graphics. Graphics animation is being enhanced by the use of linear small amplitude wave theory to model certain natural events such as ocean waves.

c. FY 1987 Planned Program and Basis for FY 1987 Request: Key universities will continue to be supplied with advanced computer resources and supporting maintenance. The price/performance ratio of symbolic computers is expected to continue to provide more symbolic computing capability for the dollar as more competitors enter this market; this will provide greater computation resources for universities without corresponding increases in funds. In this year, more of the resources will go to locations which have not received equipment in the recent past. More complex tasks will be assigned to the factory floor-roving robots as well as autonomously roving robots in dynamic environments. Work in robotic perception, manipulation, and control will progress to the point where fine discriminatory tasks such as bin picking and parts insertion will be able to be performed. Advances in robotic planning will focus on high-level instruction of robots by natural language interaction.

d. Program to Completion: Provision of advanced computer resources to universities will continue through FY 1988 at which time the planned investments will be phased down. Languages and techniques for robotic instruction will be developed and demonstrated. Emphasis will be placed on their performance in unplanned scenarios. Techniques for incorporating machine learning techniques will be used to expand the adaptability of robotic systems. Robotic systems that reason about spatial quantities, use multiple representations of objects, and maneuver in and manipulate its environment will be developed. Cooperative robotic techniques will continue to be explored and developed, as will the use of qualitative models to predict the effects of planned actions by robotic agents.

# FY 1987 RDT&E DESCRIPTIVE SUMMARY

Title: Modernization Technology  
 Title: Defense Research Sciences  
 Budget Activity: 1. Technology Base

Project: # CCS-3  
 Program Element: # 61101E  
 USDRE Mission Area: 530

## e. Milestones:

<u>Last Year's Reported Plan</u>	<u>Current Plan</u>	<u>Milestone</u>
	Mid FY 1986	Continue computer resource modernization.
	Mid FY 1986	Demonstrate improved graphic animation by modelling ocean waves.
	Mid FY 1986	Demonstrate spatial and temporal reasoning in static environments.
Mid FY 1986	Mid FY 1986	Demonstration of manipulator parts insertion.
Late FY 1986	Late FY 1986	Initial demonstration of a mobile shop robot.
	Late FY 1986	Initial demonstration of object recognition via tactile sensor.
Mid FY 1987	Mid FY 1987	Demonstrate advanced robotic planning for autonomous navigation.
	Mid FY 1987	Continue computer resource modernization.
Late FY 1987	Late FY 1987	Demonstrate initial techniques for high-level robotic instruction.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: # CCS-3  
 Program Element: # 61101E  
 USDR Mission Area: 530

Title: Modernization Technology  
 Title: Defense Research Sciences  
 Budget Activity: 1. Technology Base

Last Year's Reported Plan	Current Plan	Milestone
Late FY 1987	Demonstrate spatial and temporal reasoning in three dimensions.	
Mid FY 1988	Continue computer resource modernization.	
Late FY 1988	Demonstrate spatial and temporal reasoning in dynamic environments.	
Late FY 1988	Demonstrate robotic task improvement via machine learning techniques such as generalization, induction, or analogy.	

f. Explanation of Milestone Changes: Not Applicable.

# FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #61103E  
USDR&E Mission Area: 530

Title: University Research Initiative  
Budget Activity: 1. Technology Base

## A. RESOURCES: (\$ in Thousands)

Project Number	Title	FY 1985 Actual	FY 1986 Estimate	FY 1987 Estimate	FY 1988 Estimate	Additional to Completion	Total Estimated Costs
	TOTAL FOR PROGRAM ELEMENT	0	\$ 5,980	\$12,500	\$24,600	Continuing	N/A

B. BRIEF DESCRIPTION OF ELEMENT AND MISSION NEED: This project pursues new university based research initiatives in sciences and technologies of demonstrated or potential long term significance to the Department of Defense (DoD). The focus is on interdisciplinary research thrusts of three to five years duration which promise unique and innovative technological breakthroughs for use in the design and fabrication of future DoD systems. Particular emphasis is placed on efforts which couple computationally intense modelling and theoretical calculations exploiting the new generation of relatively low cost multiprocessor system architecture using advanced software and systems technologies with a viable experimental program to guide and verify the modelling/theory. Technical areas addressed include: fluid dynamics in physical phenomena involving the transition to turbulent flow; monomolecular and thin film multilayer metal, semiconductor, organic, and electro-optic structures exhibiting quantum and other size effects; application of expert systems and sensors (machine and artificial intelligence) to the design and fabrication of complex parts and materials; fabrication and mechanical behavior of composite materials; and behavior of materials under extremely fast loading. Each initiative addresses funding for experimental and multiprocessor computational equipments and instrumentation as well as faculty, graduate fellowships and research assistantships and materials necessary to execute the project.

C. COMPARISON WITH FY 1986 DESCRIPTIVE SUMMARY: Not Applicable.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #61103E  
USDR&E Mission Area: 530

Title: University Research Initiative  
Budget Activity: 1. Technology Base

D. OTHER APPROPRIATION FUNDS: Not Applicable.

E. RELATED ACTIVITIES: Defense Research Sciences (DRS) within Army, Navy, Air Force and DARPA provides broad support to the engineering and science disciplines of long term significance to the Department of Defense. This project will strengthen the DRS efforts substantially by supporting comparatively large (\$1M-\$6M/year/contract) and major equipment purchases (e.g., \$0.5M-\$3.0M) which cannot be accommodated in existing research program structures. These multi-disciplinary efforts exploit emerging, high leverage scientific opportunities for defense needs, fill gaps in the existing national research and development program, and meet threats of foreign domination of a science or technology.

F. WORK PERFORMED BY: This project is performed by universities selected on a competitive basis.

G. PROJECTS LESS THAN \$7 MILLION IN FY 1987: Not applicable.

H. PROJECTS OVER \$7 MILLION IN FY 1987:

1. Project Description: This project explores defense relevant, innovative research concepts in the engineering and physical sciences in a sufficiently early stage of development that they are best addressed through focussed, interdisciplinary, university based research initiatives. Each initiative is of three to five years duration, emphasizes funding for necessary instrumentation, and provides post-doctoral and graduate assistantships as well as other necessary support to implement its research plan. Particular emphasis is placed on initiatives which combine theoretical modelling made possible by relatively inexpensive new, multiprocessor system architectures with a robust experimental program to verify and guide the theoretical effort. Specific initiatives are selected on the basis of the opportunity to exploit emerging, high leverage scientific opportunities which address urgent defense needs, fill large gaps in the national research and development program, and meet threats of foreign domination.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #61103E  
USDR&E Mission Area: 530

Title: University Research Initiative  
Budget Activity: 1. Technology Base

2. Program Accomplishments and Future Programs:

a. FY 1985 Accomplishments: Not Applicable. This is a new start in FY 1986.

b. FY 1986 Program: This project is being announced and described to the academic community through Commerce Business Daily notices and briefings to the research community at conferences and other appropriate meetings. Short draft planning proposals are being sought from which a government technical evaluation team will select the best for small awards to partially support costs of preparing formal proposals. It is anticipated that two to four awards will be made. Initial funding will emphasize acquisition and/or design and fabrication of state-of-the-art equipment and multiprocessor systems such as those being developed by the Strategic Computing Program to provide supercomputational capability necessary for the research efforts, and establishment of necessary research assistantships/fellowships. Advanced software and systems concepts will be used to advance the state-of-practice toward the state-of-the-art. Subsequent years also will maintain an equipment support level (25-33 percent of annual funding) to provide for maintenance and updating. Proposal selection criteria will include: originality and potential impact of proposed research including the degree of interdisciplinarity; demonstrated quality of research staff and graduate students as evidenced by prior and on-going research achievements, especially in research pertinent to the proposed effort; university commitment to the research area as evidenced by facility investment, faculty tenure track appointments, and research support from other sources; the extent to which industrial interactions are evident; and viability of a long term plan for initiative completion or to develop support for continuation as the DARPA program nears completion in the five or so year timeframe.

c. FY 1987 Planned Program and Basis for FY 1987 Request: A second competitive round seeking research initiatives will be executed in FY 1987. Initiative areas will be considered in addition to fluid mechanics, thin films, expert systems in manufacturing, and composite materials, such as: synthesis of new materials with tailored electromagnetic properties; chemistry of highly energetic materials; ultraviolet and visible laser-material interactions; and integrated optoelectronic circuit design and processing. Research efforts initiated in FY 1986 will complete purchase and/or construction

# FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #61103E  
USDP&E Mission Area: 530

Title: University Research Initiative  
Budget Activity: 1. Technology Base

and installation of instrumentation and equipment phases, and achieve the full level of research operations by the end of FY 1987. Research accomplishments will be forthcoming from these efforts beginning in mid FY 1987.

d. Program to Completion: All initiatives will be underway by the end of FY 1987. In FY 1988-FY 1990 research results will be accumulated for each; those showing great promise for major impact on technical capabilities significant to DoD will begin transition to exploratory development in DARPA and the Services. Program will be completed in FY 1991.

## e. Milestones:

<u>Last Year's Reported Plan</u>	<u>Current Plan</u>	<u>Milestone</u>
N/A	Early - FY 1986	Complete announcements of program.
N/A	Mid - FY 1986	Complete proposal evaluation and selection.
N/A	Late - FY 1986	Contract awards.
N/A	Early - FY 1987	Second round of proposal solicitation.
	Late - FY 1988	Evaluation of progress on FY 1986 contracts and selection of those for continual support.

f. Explanation of Milestone Changes: No milestones were reported in the FY 1986 descriptive summary.

# FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #62101E  
 USDR&E Mission Area: 530

Title: Technical Studies  
 Budget Activity: 1. Technology Base

## A. RESOURCES: (\$ in Thousands)

Project Number	Title	FY 1985 Actual	FY 1986 Estimate	FY 1987 Estimate	FY 1988 Estimate	Additional to Completion	Total Estimated Cost
TOTAL FOR PROGRAM ELEMENT		\$1,500	\$1,500	0	\$1,700	Continuing	N/A

B. BRIEF DESCRIPTION OF ELEMENT AND MISSION NEED: This program provides independent, topical, in-depth studies and analyses in support of the Office of the Under Secretary of Defense for Research and Engineering (OUSDR&E), and its various component offices. Each year the most urgent subjects are chosen by the directors of Strategic and Theater Nuclear Forces, Tactical Warfare, Research and Advanced Technology and others. The Institute for Defense Analyses (IDA) provides in-depth answers to current and anticipated future problems assisting the decision makers to make better informed judgements and decisions.

C. COMPARISON WITH FY 1986 DESCRIPTIVE SUMMARY: No funds are required in FY 1987 due to planned late obligation of FY 1985 and FY 1986 funds. Funds will again be requested in the FY 1988 budget submission.

D. OTHER APPROPRIATION FUNDS: None.

E. RELATED ACTIVITIES: The work performed under this program element is related to and contributes data to the program management activities of OUSDR&E. Specific offices that have been supported include those of the Deputy Under Secretaries, Defense Research and Engineering (DUSDR&E) for: Research and Advanced Technology; Tactical Warfare Programs; and Strategic and Theater Nuclear Forces and International Programs and Technology.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #62101E  
USDR&E Mission Area: 530

Title: Technical Studies  
Budget Activity: 1. Technology Base

F. WORK PERFORMED BY: This research is performed by the Institute for Defense Analyses (IDA),  
Arlington, Virginia (FFRDC, 100%).

G. PROJECTS LESS THAN \$7 MILLION IN FY 1987: Not applicable.

H. PROJECTS OVER \$7 MILLION IN FY 1987: Not applicable.

**FY 1987 RDT&E DESCRIPTIVE SUMMARY**

**Program Element: #62301E**  
**USDR&E Mission Area: 530**

**Title: Strategic Technology**  
**Budget Activity: 1. Technology Base**

**A. RESOURCES (Project Listing): (\$ in Thousands)**

<u>Project Number</u>	<u>Title</u>	<u>FY 1985 Actual</u>	<u>FY 1986 Estimate</u>	<u>FY 1987 Estimate</u>	<u>FY 1988 Estimate</u>	<u>Additional To Completion</u>	<u>Total Estimated Costs</u>
	<b>TOTAL FOR PROGRAM ELEMENT</b>	<b>152,771</b>	<b>239,370</b>	<b>240,620</b>	<b>259,500</b>	<b>Continuing</b>	
ST-1	Advanced Strategic Concepts & Strategic Technical Analysis	5,652	5,861	6,065	3,450	Continuing	N/A
ST-5	Hypersonic Flight Technology	12,021	20,000	-0-*	-0-*	-0-	N/A
ST-6	Warning Technology	12,630	-0-	-0-	-0-	-0-	96,391
ST-7	Special Applications Technology	5,825	-0-	-0-	-0-	Continuing	N/A
ST-9	Submarine Laser Communications	32,900	25,330	5,645	-0-	-0-	N/A
ST-10	Strategic Computing	63,662	142,451	146,000	150,000	Continuing	N/A
ST-11	Intelligent Systems	20,081	24,570	30,358	35,225	Continuing	N/A
ST-12	Advanced Quantum Electro-Optics	-0-	15,683	33,956	44,200	Continuing	N/A
ST-13	Strategic Air Cruise Missile Defense	-0-	5,475	18,596	26,625	Continuing	N/A

\* Project transitions to a new Program Element (PE 63269E) in FY 1987 and beyond.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #62301E  
USDR&E Mission Area: 530

Title: Strategic Technology  
Budget Activity: 1. Technology Base

B. BRIEF DESCRIPTION OF ELEMENT AND MISSION NEED: This Program Element in FY 1987 funds a broad and comprehensive research and development program directed toward the development and application of advanced technologies associated with advanced strategic system concepts; strategic communications and signal processing; submarine laser communications; strategic computing; intelligent systems; advanced electro-optics; and advanced radar techniques.

The Advanced Strategic Concepts and Technical Analysis Project identifies and evaluates advanced strategic system concepts and system technologies in order to define critical technological issues and establish experimental efforts which are: to provide a basis for defining and evaluating the implications of technology on future weapons system designs and capabilities; to develop new initiatives that could significantly alter military effectiveness; to assess the implications of new technology on strategic policy and conversely the technological implications of new strategic policy; and to support the Office of the Under Secretary of Defense for Research and Engineering (OUSDR&E) in establishing feasibility and priorities on present and proposed R&D programs and to technically evaluate the technological and capability implications of various treaty provisions. This project includes Strategic Communications which is demonstrating a vertical Very Low Frequency/Extremely Low Frequency (VLF/ELF) communications technologies and AM internetting.

The Hypersonic Flight Technology (formerly Strategic Delivery Vehicles) project developed new technologies in airbreathing propulsion; strong, lightweight, high temperature materials; and cryogenic hydrogen utilization. These technologies are applicable to the next generation strategic vehicles having capabilities to fly within the atmosphere at unprecedented speeds and altitudes. They are also applicable to the next generation space launch system capable of much reduced cost to orbit. This project transitions to a new separate Program Element (PE 63269E) in FY 1987 and beyond.

The Warning Technology Project was terminated in FY 1985 and consisted of Detection of Aircraft - HI-CAMP (TIARA) (transitioned to Program Element 63226E, Project EE-17 in FY 1986); Precision Pointing - Teal Emerald (transitioned to Project ST-12 in FY 1986); and Detection from Space (transitioned to the President's Strategic Defense Initiative (SDI) program in FY 1985 Program Element 63220C).

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #62301E  
USDR&E Mission Area: 530

Title: Strategic Technology  
Budget Activity: 1. Technology Base

The Special Application Technology Project terminated in FY 1986 and consisted of two thrusts: Strategic Communications and the Acoustic Charge Transport (ACT). Strategic Communications was transferred in FY 1986 to the Strategic Concepts and Analysis Project (ST-01). The Acoustic Charge Transport (ACT) Program was transferred to the Tactical Technology Program Element (PE 62702E; Project TT-05).

The Submarine Laser Communications (SLC) Project is developing the technology necessary for providing critical underwater communications using blue-green lasers. The specific payoffs of this technology would be: (1) providing critical messages to Fleet Ballistic-Nuclear Missile Submarines (SSBNs) at depth without compromising the submarine's natural covertness, thus helping to ensure the SSBN force's continued high level of survivability; (2) increased robustness and survivability of the Command, Control and Communications (C3) system well into the post-attack period; (3) allowing the Nuclear Submarine (SSN) to work most effectively in its own environment while providing threat and target intelligence information to it in real time; and (4) controlling a broad variety of pre-placed underwater assets, such as minefields and acoustic arrays.

The Strategic Computing Project is an effort to develop and demonstrate super intelligent computers for application to critical problems in defense. It draws directly on the basic research results from the Intelligent Systems Project (ST-11), and augments them to provide specific future defense capabilities using advanced computer technology.

The Intelligent Systems Project undertakes fundamental investigations into the limits of the digital computer's capabilities for intelligent processing in selected areas of military relevance. The results of this basic research are to be exploited in the Strategic Computing Project (ST-10).

The Advanced Quantum Electro-Optics Project is to develop optical technologies to make possible a broad range of new military capabilities, including ultra long range space imaging from the ground, long range endo-atmospheric imaging systems, and space-based and airborne optical detection.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #62301E  
USDR&E Mission Area: 530

Title: Strategic Technology  
Budget Activity: 1. Technology Base

Strategic Air Cruise Missile (SACM) Defense is a new project, consolidating previous efforts under Project ST-1. The objectives are to identify and to develop techniques for surveillance of aircraft and cruise missiles. Mission functions addressed include surveillance (acquisition, track, identification), targeting and kill assessment. The SACM Program will develop system concepts, associated technologies, and an architecture to provide the building blocks for advanced strategic surveillance capability. The goal is to achieve order-of-magnitude sensitivity improvements compared to existing surveillance systems.

C. COMPARISON WITH FY 1986 DESCRIPTIVE SUMMARY:

Advanced Strategic Concepts and Strategic Technical Analysis - FY 1986 funding did not change but FY 1985 funding increased due to added requirements relating to the new Strategic Air Cruise Missile defense initiative. FY 1986 funding increased due to the addition of the Strategic Communications Program within this project.

Hypersonic Flight Technology - As indicated in the FY 1986 Descriptive Summary, a new thrust in Hypersonic Technology for advanced air vehicles (previously called Copper Canyon) was initiated. This project transitions to new Program Element (63269E) in FY 1987 where the FY 1986 and 1987 comparison is addressed.

Warning Technology - FY 1986 and outyear funding has been eliminated due to the transition of the Highly Calibrated Airborne Measurement program (HI-CAMP) to a demonstration program funded in PE 63226E project, EE-17, and the transfer of precision pointing technology to a new project, ST-12.

Special Applications Technology - FY 1986 and out year funding been eliminated due to the transfer of its two programs to other Projects described earlier.

Submarine Laser Communications - FY 1985 and FY 1986 funding has decreased due to congressional budget reductions.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #62301E  
USDR&E Mission Area: 530

Title: Strategic Technology  
Budget Activity: 1. Technology Base

Strategic Computing - FY 1986 and FY 1987 funding has decreased due to congressional budget reductions.

Intelligent Systems - This is a new project in FY 1986 due to Congressional redirection of Project No. CCS-01 from PE 61101E, in FY 1985. The FY 1986, 1987 and 1988 funding has not changed.

Advanced Quantum Electro-Optics - This is a new project starting in FY 1986. FY 1986 and 1987 funding has decreased due to reduced project requirements reflecting Congressional and Defense Department budget reductions.

Strategic Air Cruise Missile (SACM) Defense - This is a new project starting in FY 1986 utilizing basic efforts funded in FY 1985 in Project ST-1. FY 1986 and FY 1987 funding has decreased due to restructured project requirements.

D. OTHER APPROPRIATION FUNDS: Not applicable.

E. RELATED ACTIVITIES: (Projects with FY 1987 Funding)

The Advanced Strategic Concepts and Strategic Technical Analysis project relates directly to programs of the Office of the Under Secretary of Defense for Research and Engineering, the Air Force Aeronautical Systems Division, the Army Ballistic Missile Defense Advanced Technology Center, the Air Force Space Division, the Air Force Rome Air Development Center, and the Naval Undersea Systems Center.

The Hypersonic Technology project in FY 1987 transitions to a new Program Element (63269E) where related activities are addressed.

For the Submarine Laser Communications Project there are several supporting Navy programs in areas such as blue-green laser technology and optical oceanography. Other major technology areas, such as space optical systems and atmospheric compensation, are coordinated with ongoing Air Force, Navy, and DARPA programs through a variety of formal and informal mechanisms including joint use of facilities, personnel, and contracting agents.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #62301E  
USDR&E Mission Area: 530

Title: Strategic Technology  
Budget Activity: 1. Technology Base

In Strategic Computing the Defense Software Technology Initiative will augment this effort by developing single processor software environments based on the Ada Programming language and by providing Ada Programming Support Environments to support conventional software practices. The Very High Speed Integrated Circuit program is addressing special purpose Very Large Scale Integrated chips for military signal processing applications. The S-1 multiprocessor system under development by the Navy and Department of Energy is exploring one approach to multiprocessor architecture potentially useful for superspeed computer applications. National Bureau of Standards will support maintenance and dissemination of speech databases developed under this program to the research community at large and will support multiprocessor system architecture benchmarking activities. The Services, National Security Agency, and Central Intelligence Agency have all initiated Artificial Intelligence (AI) Centers that offer the potential of contributing technology to, and using the technology developed by the generic AI component of this effort. The Supercomputer Research Division of Institute for Defense Analyses, established by DoD, will assist in the evaluation of selected multiprocessor system architectures.

Intelligent Systems: The National Science Foundation, the National Institute of Health, the National Aeronautics and Space Administration, the Office of Naval Research, the Air Force Office of Scientific Research, the Naval Research Laboratory, the Naval Electronic Systems Command, the Defense Mapping Agency, Rome Air Development Center, the Army Engineering Topographic Laboratory, and Air Force Avionics Laboratory also support artificial intelligence research. These efforts address image understanding, expert systems technology, industrial automation, analytical chemistry, immunology, natural language understanding, deep-space and undersea probes, information fusion and management decision aids. Techniques developed in this project have widespread applicability throughout the Defense Department. Close coordination with prospective users is maintained through workshops, site visits, the choice of contracting agents, and joint programs. Examples of joint programs include the image understanding and natural language database interface work being performed in conjunction with the Defense Mapping Agency and the image understanding for port monitoring work conducted with the Central Intelligence Agency and Office of Naval Research. In the area of software generation, the Ada Joint Projects Office (AJPO) is funding work in software engineering and a new government Software Engineering Institute is to be developed. DARPA's work in new-generation software development involves more advanced research and complements the other software engineering work described above.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #62301E  
USDR&E Mission Area: 530

Title: Strategic Technology  
Budget Activity: 1. Technology Base

**Advanced Quantum Electro-Optics:** The portion of this effort which is developing advanced space imaging technology will be fully coordinated, through technical interchange meetings, with related Air Force programs currently ongoing at Rome Air Development Center, Air Force Space Division and Air Force Space Command.

The Strategic Air Cruise Missile Defense project will focus on ongoing DARPA surveillance efforts such as, Teal Ruby and HI-CAMP. The program will be managed with the help of a steering committee with Army, Navy and Air Force participation to coordinate internal service programs.

F. WORK PERFORMED BY: (Projects with FY 1987 Funding)

**Advanced Strategic Concepts and Strategic Technical Analysis:** All of the project efforts are conducted by industry. The major contractors are: General Research Corporation, Santa Barbara, California; Toyon Research, Santa Barbara, California; Analytical Decisions, Inc., Arlington, Virginia; Directed Technologies Inc., McLean, Virginia, and MIT Lincoln Laboratory, Lexington, Massachusetts; and Pacific-Sierra Research Corporation, Los Angeles, California.

**Hypersonic Flight Technology Project:** Refer to Program Element (63269E).

**Submarine Laser Communications:** 85% industry, 2% universities, and 13% government in-house laboratories. Contractors include: Hughes Aircraft Company, Los Angeles, California; McDonnell Douglas Astronautics Company, St. Louis, Missouri; GTE Sylvia, Mountain View, California; Lockheed Missiles and Space Company, Palo Alto, California; RCA Government Systems Division Moorestown, New Jersey; Spectra Diode, San Jose, California; Spectra Technology, Bellevue, Washington; Sanders Associates, Nashua, New Hampshire; Lawrence Livermore National Laboratory, Livermore California. The university work is being done by the University of California's Scripps Institute of Oceanography, San Diego, California; and the University of Arizona's Optical Science Center, Tucson, Arizona. In-house effort is being funded at the Naval Ocean Systems Center, San Diego, California and the Naval Research Laboratory, Washington, D.C.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #62301E  
USDR&E Mission Area: 530

Title: Strategic Technology  
Budget Activity: 1. Technology Base

Strategic Computing: 43% university, 43% industry, and 14% in-house. The major performers are Bolt, Beranek and Newman, Cambridge, Massachusetts; Carnegie-Mellon University, Pittsburgh, Pennsylvania; Columbia University, New York City, New York; Martin-Marietta Corp, Denver, Colorado; Massachusetts Institute of Technology MIT, Cambridge, Massachusetts; MIT Lincoln Laboratory, Lexington, Massachusetts; National Bureau of Standards, Gaithersburg, Maryland; Naval Ocean Systems Center, San Diego, California; Rockwell International, Thousand Oaks California; Stanford University, Stanford California; Texas Instruments, Inc., Dallas, Texas; Thinking Machines, Inc., Cambridge, Massachusetts; University of Maryland, College Park, Maryland; and University of Southern California, Information Sciences Institute, Marina Del Ray, California.

Intelligent Systems: 35% industry, 58% university, 7% in-house. Major performers are Bolt, Beranek and Newman, Cambridge, Massachusetts; Carnegie-Mellon University, Pittsburgh, Pennsylvania; Columbia University, New York City, New York; Environmental Research Institute of Michigan, Lansing, Michigan; ESL, Inc., Mountain View, California; Hughes Research Lab., Malibu, California; Kestrel Institute, Palo Alto, California; Massachusetts Institute of Technology, Cambridge, Massachusetts; Rutgers University, New Brunswick, New Jersey; Rand Corp., Santa Monica, California; SRI International, Menlo Park, California; Stanford University, Stanford, California; University of California, Berkeley, California; University of Massachusetts, Amherst, Massachusetts; University of Rochester, Rochester, New York; University of Southern California, Los Angeles, California; and Yale University, New Haven, Connecticut.

Advanced Quantum Electro-Optics: It is anticipated that 60% of this effort will be conducted by industry, 30% by universities and 10% by government laboratories.

The Strategic Air Cruise Missile Defense project competed source selection based on an industry briefing and survey. Industrial contractors will compose 95% of the effort with the remainder performed by the Institute for Defense Analysis, Alexandria, Virginia.

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G. PROJECTS LESS THAN \$7 MILLION IN FY 1987:

Advanced Strategic Concepts and Strategic Technical Analysis - This project supports the Office of the Under Secretary of Defense for Research and Engineering (Strategic and Tactical Nuclear Forces) (OUSDR&E (S&TNF)) in establishing feasibility and priorities on present and proposed R&D programs and to technically evaluate the technological and capability implications of various policy and treaty provisions. This effort in FY 1985 and FY 1986 provided basic analytical feasibility for strategic programs for OUSDR&E (S&TNF). In Strategic Communications, the Aerostat Supported ELF/VLF Transmitter transmittable communication system is a preattack/post attack, survivable Emergency Action Message (EAM) system supporting the Fleet Ballistic Missile Force. AM Internetting uses the AM radio broadcast stations to establish a network capable of surviving an Electromagnetic Pulse attack and transmitting the EAM and conference voice. Voice capabilities from AM internettted stations are achievable without normal programming interference by applying advanced modulation schemes and advanced voice encoder equipment. To support strategic communications, monolithic array module technology in the 40-100 gigahertz region are being developed to provide low cost satellite terminals.

FY 1985 accomplishments include OUSDR&E (S&TNF) directed studies in bomber modernization issues; strategic air defense penetration; and bomber force sustainability. New initiatives in FY 1985 included DARPA directed studies in technologies for hybrid bistatic radar concepts; imprecisely located target detection; analog cryptography; and meteor burst electronic warfare. FY 1985 efforts include the imprecisely located target detection study; and the initiation of air vehicle target detection called Advanced Air Defense which is being transferred in FY 1986 to a new project number ST-13. In Strategic Communications, detailed VLF/ELF designs at subsystem level and parts/equipment were completed and procurement began. Work on EHF devices is continuing.

Support in FY 1986 continues for OUSDR&E (S&TNF) in evaluating the impacts and technology needs for survivability, endurance and effectiveness of strategic forces. Two continuing efforts will assess modernization of the airbreathing leg of the TRIAD (and associated weaponry) and wartime endurance of strategic forces. Fabrication, assembly and checkout of electrical and mechanical Very Low Frequency/Extremely Low Frequency (VLF/ELF) subsystems will be conducted in the Strategic Communications Program.

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FY 1987 objectives will be similar to those in FY 1985 and FY 1986. Specific efforts will be selected on the basis of highest potential payoff and relative importance of strategic issues addressed. In Strategic Communications, VLF/ELF experimentation including field strength and pattern measurements will begin. A demonstration of transmission between a fixed antenna and a submerged submarine will be conducted. Investigations of transportability and setup times will be made at the completion of the fixed site tests.

Submarine Laser Communications: The most important progress made during FY 1985 has been in the gradual, orderly transition of responsibility for the effort from DARPA to the Navy. For several years the Naval Electronic System Command, now Space and Naval Warfare Systems Command (SPAWAR) has been the primary agent for SLC work. In the spirit of the Navy/DARPA Memorandum of Agreement of August 1984, DARPA yielded to SPAWAR general control of experiments and the atomic resonance filter receiver development, even though DARPA continued to provide the major share of the funding for these efforts. The other and most expensive piece of the baseline technology, the space qualifiable transmitter, was directed by DARPA in FY 1985 via a SPAWARSYSCOM contract, and with management and technical direction from the Naval Ocean Systems Center. The SLCAIR cloud-measurement experiment was conducted in November and December 1984. The results from this experiment, as well as those experiments conducted earlier in 1984, showed our environmental models to be overly conservative. The performance improvements implied by these results will help reduce the cost of an eventual laser communications system. Data was also taken during this experiment by an Air Force C-135 which flew below the clouds and was equipped with an optical communications receiver.

Continuing efforts are being expended in FY 1986 to effect a smooth transition of program control and of technology from DARPA to the Navy. Advanced program planning for an operational system is now entirely a Navy function. DARPA retains direction of the space-qualifiable Laboratory Transmitter Module (LTM), the fabrication of which is nearing completion, but the product and data from the LTM contract is being tailored to the Navy's needs as a result of direct coordination with the Navy Space and Warfare Systems Command and the Naval Ocean Systems Center. Life testing of a laser device using the same blue Xenon Chloride, Raman-shifted technology as LTM has commenced. Reliability and degradation data over more than a billion pulses is being taken and applied to the LTM project.

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The first test uses a green laser transmitter installed on a Navy P-3 aircraft to pass messages to a deeply submerged submarine. Considerable effort is being expended to make exhaustive measurements of factors of use to Navy plans for developing an operational system. Transmitters and receivers are being developed for further experiments using the blue light technology needed for an operational system. Although DARPA has contributed almost \$16 million toward this effort, the Navy has been allowed full project control. This has been done in order to assist the transition of Submarine Laser Communications SLC from DARPA to the Navy. An effort to explore the potential improvements to the baseline system using solid state lasers is continuing at the Lawrence Livermore National Laboratory and elsewhere. Portions of this program at Livermore are now being funded by other DARPA lines to develop solid-state lasers for other military purposes. FY 1987 will mark the end of DARPA's direct involvement in Submarine Laser Communication as the program is transferred to the Navy. The submarine receiver effort will become entirely Navy funded as will the final preparation for the demonstration. DARPA support for the Naval Ocean Systems Center's SLC work will be reduced to include only the transmitter effort while the Navy will fund the other areas. The space qualifiable Laboratory Transmitter Module will be tested to over 200 million pulses. Design and test data will be used by the Navy to determine whether to go ahead with full scale system development of an operational satellite-to-submarine communication system using this technology. DARPA will be developing the most promising solid-state transmitter candidates which may have emerged in FY 1986. One of these may provide a potential block-replacement for the first operational transmitter, but it is expected that solid-state systems will still be two to four years behind the baseline Xec1 system. By 1988 the Navy will control SLC entirely. Residual, long-range, technology development will be transferred to other DARPA programs.

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#### H. PROJECTS OVER \$7 MILLION IN FY 1987:

1. Project Description: The objective of the Strategic Computing Program is to develop and demonstrate a new generation machine intelligence technology that can be exploited both to create advanced military systems and to maintain U.S. world leadership in computer technology. The basis for this revolutionary new generation machine intelligence technology are recent advances in artificial intelligence, computer systems, and microelectronics. The main components of the Strategic Computing Program are Military Applications, Technology Base, and Infrastructure. The current Military Applications projects include an Autonomous Land Vehicle (ALV), systems for Naval Fleet Command Center Battle Management Project (FCBMP) and for Army Airland Battle Management (ALBM), a Pilot's Associate system, and a system for Radar/Optical Imagery Analysis. The role of the applications projects is to provide a realistic task environment for the creation of an advanced, systems level, machine intelligence technology. Also, these projects are designed to serve as the principal means of demonstrating the emerging technology and of transferring it to military systems and to the industrial base. The main research areas in the Technology Base are Machine Intelligence, Machine Architectures, and Microelectronics. The current machine intelligence projects are focusing on Vision, Speech, Natural Language Processing, and Expert Systems. The goals of the research in machine intelligence are to attain major advances in functional capabilities of information processing systems, of the types required in the Military Applications projects. Research on Machine Architectures is being directed to very-high performance multiprocessor systems with performance improvements over conventional uniprocessor systems of 2-3 orders of magnitude. Multiprocessor system architectures which are suitable for both symbolic and large scale numeric applications will be developed. Also, software and design/analysis tools for these very-high performance computers will be built. The increased computing capabilities expected from the new architectures are intended to provide the real-time performance required by the machine intelligence systems developed in the program. Very large scale integrated systems and fabrication technology will be developed to enable

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rapid prototyping of integrated circuits and multiprocessor systems. Advances derived from the microelectronics research, such as techniques for new wafer-scale integration, and optoelectronic approaches for component interconnection and packaging will provide the enabling technology necessary to implement the new multiprocessors to meet military requirements. The Infrastructure component of the Strategic Computing Program provides network communications to link researchers, access to common computing resources including new multiprocessor architectures, software and systems standards to enable effective transition and to provide a convenient programming environment, and access to an integrated circuit fabrication service for custom designs.

#### 2. Program Accomplishments and Future Programs:

a. FY 1985 Accomplishments: Key Military Applications projects were started. The Autonomous Land vehicle was engineered and initial road following demonstrations, showing an improvement factor of 100 over prior capability, were carried out. Contracts were awarded to initiate the Naval Fleet Command Center Battle Management Project (FCBMP) Testbed at CINCPACFLT. The computing hardware for the Navy FCBMP Testbed was installed at CINCPACFLT headquarters. Knowledge engineering was begun with the CINCPACFLT staff for the Force Readiness Expert System (FRESH) designed to monitor changes in Fleet wide readiness. Competitive procurements were initiated for the Pilots' Associate project and the Army Airland Battle Management (ALBM) project. Also, in the ALBM program, a working expert system and LISP work station were installed at the Army's 9th Infantry Division. Contracts were awarded for the Imagery analysis applications projects. In the machine intelligence area, research projects in computer vision, speech, natural language, and expert systems were started. In vision, an evolutionary blackboard system framework for performing vision in outdoor environments has been designed and partially implemented. Trees and other obstacles have been distinguished in an open terrain setting using stereo camera technology. In speech, a prototype implementation of multiple knowledge sources has been demonstrated; knowledge sources for acoustic

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phonetic recognition, word hypothesis, and sentence level hypothesization have been constructed. In the area of natural language, a state-of-the-art man-machine interface called IRUS, that understands but does not generate discourse, has been delivered for use in The Naval Battle Management application. A highly innovative new-generation expert system framework, called ABE, has been designed which will support knowledge acquisition and deep reasoning. This is scheduled to be inserted into the Naval Battle Management Application. In the multiprocessor system architecture area, research projects in modeling, simulation, and prototyping of new and innovative scalable signal, symbolic, and multifunction systems were started. A two-cell programmable systolic array prototype (called the WARP processor) was completed and its function and performance were demonstrated for low-level vision requirements of an autonomous land vehicle. A 16 thousand processor prototype Connection Machine was completed and demonstrated on a variety of artificial intelligence problems that benefit from such massively parallel architectures. A 128 processor Butterfly multiprocessor was completed. The tagged-token data flow architecture was emulated using a network of LISP machines and a new dynamic data flow programming language, called ID, was implemented using LISP. A small-scale version of NonVon, a fine grain tree system, was completed, and demonstrated on vision problems. A small-scale version of DADO, a medium grain tree system was completed, and demonstrated on expert systems. A design for a multiprocessor Ada compiler and run time system was completed; a parallel processing workbench was developed and demonstrated on a small-scale multiprocessor and on advanced workstations on a local area network. Design of a compact LISP machine chip and a desktop LISP multiprocessor has been completed. System performance measurement techniques based on computational models were developed and a catalog of performance measurement techniques was developed. An advanced framework for Common LISP programming environments was designed and an initial prototype started using a persistent object base. In the micro/opto-electronics area, a method of optical multiplexing and demultiplexing electronic signals on VLSI chips was developed; the feasibility of greater than 1 Gigabit/second communications was demonstrated using Gallium Arsenide integrated circuits. This represents a critical step toward developing an optoelectronic technology with reduced size, weight, and power requirements for the massive interconnection requirements of

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advanced multiprocessors. Test structures for e-beam programming of wafer scale circuits have been successfully fabricated and tested. LISP machines from various vendors that support the Common LISP standards were procured to support specific research projects. Initial network access software was completed for the Butterfly multiprocessor and several small Butterfly multiprocessors were distributed to support specific research projects. These have been used to explore applications in distributed expert systems, machine vision, and high speed combat simulation. The MOSIS custom chip system was successfully used to test advanced circuit designs using 1.25 micron CMOS.

b. FY 1986 Program: In the Military Applications, the Autonomous Land Vehicle is demonstrating autonomous road following at speeds up to 20 Kph over various road types with obstacles using the WARP and Butterfly architectures and new generation vision processing algorithms from the Technology Base. The Navy Fleet Command Center Battle Management Project (FCCBMP) force readiness expert system prototype is installed and demonstrated at CINCPACFLT headquarters along with the natural language interface. Work on the second of five expert systems, the Capabilities Assessment Expert System (CASES) is started and integrated with the ABE expert system environment. The WARP and Butterfly architectures are integrated, using a high-speed intelligent bus, into an advanced and novel image processing architecture for military image understanding applications. Initial studies suggest that this powerful combination will, for the first time, enable the real-time analysis of certain classes of radar and optical imagery. Rapid combat simulations using a multiprocessor architecture are being demonstrated for the first time in the Army Airland Battle Management Project (ALBM). The architecture for cooperating planning knowledge-based systems for Army Corps and Division headquarters and Numbered Air Force headquarters is being designed in the ALBM project. A natural language query prototype for Corps artillery will be demonstrated in the ALBM project. An architecture featuring cooperating expert systems is being designed for the Pilots Associate application project. Machine Intelligence system frameworks will be developed to enable the use of multiprocessor system architectures through the software and system standards. The implementation of the new-generation vision system framework is being completed. Recognition capabilities for

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open-terrain navigation, common representation schema for visual models and vision primitives, obstacle avoidance techniques, and the capability for detecting moving objects are being developed and will be demonstrated and evaluated in the Autonomous Land Vehicle project. The integration of various knowledge sources within a speech system framework is underway. A continuous speech system with 200-word vocabulary and an isolated word recognition system which recognizes utterances in the face of high noise and speaker stress are being demonstrated. The first version of the natural language understanding system, IRUS, is demonstrating lexical and semantic coverage in the Naval Battle Management System context. The text understanding system, PROTEUS (Prototype Text Understanding System) is being developed with a goal of attaining 80% accuracy of comprehension on a restricted class of equipment failure messages. The structure of the new-generation expert system, ABE, is being implemented, and modules for evidential reasoning, explanation, and knowledge acquisition are being incorporated. In the multiprocessor system architecture area, a 10-cell WARP programmable systolic array system is in production and a VLSI version is being designed to provide compact high performance front-end numeric computation for signal processing applications such as vision for fire and forget weapons, and for use as scalable accelerators with multifunction computer systems. A 64 thousand processor Connection Machine is being completed along with network access software and advanced system software using Common LISP. The multiprocessor emulation facility is being expanded to 32 processors, and is being used to emulate larger tagged-token dataflow architectures; and will provide a basis for designing dynamic dataflow systems. A modular signal processing architecture is being designed and prototyped to provide the performance of a hardwired heterogeneous signal processing system with the flexibility of programmable interconnection capable of supporting 2 billion floating point operations per second and programmable in ADA. The design of an advanced Connection Machine is starting that will be capable of 1 trillion bit operations per second using VLSI and VHSIC technologies. The design and initial development of a coarse grain tree system, with digital signal accelerators for speech recognition systems capable of 30 thousand dynamic operations per second is underway; it will be capable of reaching 1.5 million such operations per second with VHSIC insertion. A modular integrated system architecture for multifunction, symbolic,

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and signal processing capable of supporting 1000 processors, providing 5 billion instructions per second, and supporting 4 billion bytes of memory is being designed and prototyped and will support Common LISP and Ada. An advanced multiple instruction multiple data stream machine with 8 thousand fine grain processors will support Common LISP and ADA capable of 8 billion instructions per second with 2 billion bytes per second input/output and 128 to 512 million bytes of memory is being designed and prototyped. Several new and innovative simulation and small scale prototype projects are underway in industry and academia exploring new programming approaches for multiprocessors. A general purpose parallel multiprocessor with 64 high performance reduced instruction set 32 bit processors and floating point coprocessors, scalable to 512 processors, 1 to 2 billion bytes of main memory, 200 million bytes per second of input/output, and 12 billion bytes per second of interconnection capacity is being designed and prototyped. A Massive Memory Machine is being developed to support billions of bytes of main memory in a uniprocessor user model with additional processors transparently distributing the workload. Generic models of multiprocessor system architectures and problem domains are being developed to characterize computational power and requirements and extend the theory of computation to multiprocessor systems. Parallel software synthesis techniques are being designed and prototyped for a variety of multiprocessor system architectures using knowledge based techniques. Performance measurement methods, techniques, and tools are being developed. In microelectronics, optical links for board-to-board interconnection of the 64 thousand processor Connection Machine and the WARP programmable systolic array are being studied. Photorefractive beam scanning is being developed to provide at least a 100 times improvement in optical disk access rates. A fully solid state three dimensional vision sensor is being fabricated for the Autonomous Land Vehicle. Competing packaging techniques are being explored for achieving fiber-to-chip coupling and low loss processing transceiver chip coupling for high speed optical interconnects. A comparison of optoelectronic versus electrical chip-to-chip interconnection for VLSI circuits is being conducted. A copy of the MOSIS system, which provides fabrication services for rapid prototyping of integrated circuits and printed circuit boards, is being installed in a secure facility for use with classified design efforts. MOSIS

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is being expanded to include Gallium Arsenide. A high quality cell library is being implemented in MOSIS with quality assurance methods.

c. FY 1987 Planned Program and Basis for FY 1987 Request: In the Military Applications, the Autonomous Land Vehicle will demonstrate autonomous, cross-country, navigation over rough terrain with speeds up to 10 Kph. Vision processing, route planning and re-planning will be accomplished using on-board multiprocessors; object classification will use a multi-spectral imaging laser radar. Transfer of the technology to the Army will be focused and transitioned. The Force Readiness and Assessment Scheduler for Naval FCBMP (Fleet Command Center Battle Management Project) Testbed will be demonstrated at CINCPACFLT headquarters. Natural language text understanding with 90% accuracy will be demonstrated in the context of force readiness. The Combat Action Team expert system will be demonstrated on-board the U.S.S. Carl Vinson, CVN-70 during a major fleet exercise. Four expert systems covering the functional areas of situation assessment, mission planning, tactics and on-board system performance will be developed and demonstrated in the Pilot's Associate project. A speech understanding interface appropriate for the noisy cockpit environment will be demonstrated. Strategic force monitoring will be demonstrated in the image understanding application. Cooperative maneuver planning between the Corps and Division headquarters which demonstrates interactive plan generation, dynamic plan evaluation on a parallel architecture, and intelligent operation order generation will be developed in the ALBM prototype. Multiprocessor system architectures that support the Technology Base software and system standards will facilitate the transition of new-generation machine intelligence technologies in the applications. A new-generation vision system to support early off-road vision requirements of the autonomous land vehicle will be completed. Continuous speech research efforts will develop a 1000-word recognition system that deals with largely unrestricted vocabularies, and will be interfaced as a voice querying system to a battle management database. Technology will be adapted from the continuous domain to provide faster connected word systems for more restricted environments such as the fighter cockpit. JANUS will demonstrate a language generation capacity. PROTEUS (Prototype Text Understanding System) will achieve a degree of accuracy

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of 90% on text understanding, and common sense reasoning about causes of equipment failures will be introduced to permit extension of knowledge about failures to broader classes of devices. A new-generation expert system architecture will become available for exploitation on military applications. Performance evaluation methods will be developed for the new-generation machine intelligence systems. Transition of the new-generation systems to multiprocessor system architectures will begin. A medium scale modular signal processing architecture will be demonstrated. Advanced software for the Connection Machine will be available for use in a Common LISP environment and the network access software will be completed. Prototype development of an advanced connection machine will begin. A medium scale prototype of DADO with digital signal processor accelerators will be developed and demonstrated on speech processing. A medium-scale modular integrated system architecture for multifunction/symbolic/signal processing will be developed. A medium scale coarse grain shared memory multiprocessor system will be developed. New signal processing models, theories, and reconfigurable systems will be developed. The Massive Memory Machine prototype system will be available as a network server. A small scale tagged token dataflow system will be developed. Common LISP will be completed for the Butterfly multiprocessor. Accelerators for logic programming execution will be designed and fabricated in VLSI. A 1.2 micron CMOS RISC processor for Common LISP will be demonstrated. Parallel software synthesis for a variety of multiprocessor system architectures using a knowledge base approach will be developed and demonstrated. Performance evaluation methods for Multiprocessor system architectures will be developed and applied. In the optoelectronics area, a wideband optoelectronic crossbar that is at least 32 by 32 will be designed and built. Gallium Arsenide and silicon circuits will be fabricated on sapphire substrates to provide a monolithic optoelectronic capability for silicon integrated circuits. Optical read/write media will be developed with a capacity 10 times the current state-of-the-art. In the infrastructure, the MOSIS system will continue to provide fabrication services for both silicon and Gallium Arsenide circuits, as well as printed circuit boards for use in prototyping new system architectures.

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d. Program to Completion: Current applications projects will be concluded and the systems level technologies developed will be transferred into military systems. The military applications will be focused to take advantage of the opportunities provided by increasingly more advanced Strategic Computing Program technologies. Candidates include SAC targeting/re-targeting, new-generation "intelligent" seekers for fire-and forget weapons, automation of high-cost weapons production lines, location of fleeting, or imprecisely located, targets, and logistics re-supply. New generation machine intelligence systems will be implemented on multiprocessor systems and demonstrated in military applications projects. The homogeneous scalable multiprocessors will be used as an extensible base to develop heterogeneous systems with extensible object oriented software. The functionality of the machine intelligence systems will be extended to provide improved knowledge acquisition, knowledge representation, reasoning, explanation, man-machine interfaces, distributed processing, and multiprocessor implementations. Work on multiprocessor system architectures and software will continue leading to the development of a new generation of systems with 3 to 4 orders of magnitude increase in performance. Infrastructure support for the program will be expanded to upgrade the experimental environment to include the new multiprocessor system architectures and advanced VLSI capabilities.

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#### e. Milestones:

<u>Last Year's Reported Plan</u>	<u>Current Plan</u>	<u>Milestone</u>
Mid FY 1986	Early FY 1986	Initial Emulation Facility operational.
Late FY 1985	Mid FY 1986	Beam Processed, customized IC interconnection demonstrated.
Late FY 1986	Late FY 1986	Demonstrate Obstacle Avoidance on Autonomous Land Vehicle.
Late FY 1986	Late FY 1986	Design of low cost symbolic processing machine completed.
Late FY 1986	Late FY 1986	Demonstrate fully operational dataflow emulation facility.
Early FY 1987	Early FY 1987	Initial data flow emulator completed.

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Last Year's Reported Plan	Current Plan	Milestone
	Early FY 1987	Demonstrate ultra-rapid expert system running with a large set of rules on the ASPRO parallel processor.
	Early FY 1987	Compact Lisp machine for military use demonstrates 10 times the performance of larger conventional Lisp processor.
Mid FY 1987	Mid FY 1987	Innovative multi-processor architectures demonstrated with speed potential of 1000 times conventional architectures with comparable technology speeds.
	Mid FY 1987	Combat Action Team expert system demonstrated on U.S.S. Carl Vinson, CVN-70.
	Mid FY 1987	Force Readiness and Assessment Scheduler for Naval Battle Management demonstrated at CINCPFLT.
	Mid FY 1987	Demonstrate open country off road navigation with the autonomous land vehicle.
	Mid FY 1987	Demonstrate CASES full system architecture at FCCBMP Testbed.

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<u>Last Year's Reported Plan</u>	<u>Current Plan</u>	<u>Milestone</u>
	Mid FY 1987	Natural language understanding with high accuracy, in selected context of Naval battle management and force/equipment readiness.
	Mid FY 1987	Massive Memory Machine available on the ARPANET.
	Late FY 1987	Demonstrate cooperating maneuver planning expert systems at Corps and Division level for Airland Battle Management.
	Late FY 1987	Initial prototype of software planning system tool for clonable Airland Battle Management knowledge-based systems.
	Late FY 1987	Initial speech interface to Airland Battle Management prototype.
	Late FY 1987	Photorefractive beam scanning demonstration.
	Late FY 1987	Strategic bomber base vision expert system demonstration.
	Late FY 1987	Provide Gallium Arsenide fabrication in MOSIS.

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<u>Last Year's Reported Plan</u>	<u>Current Plan</u>	<u>Milestone</u>
Late FY 1987	Late FY 1987	Demonstrate JANUS (Natural Language follow-on to IRUS) at FCCBMP Testbed.
Late FY 1987	Late FY 1987	Continuous speech recognition in a task environment with a large word vocabulary.
Late FY 1987	Late FY 1987	Four cooperating expert systems with speech understanding man-machine interface in the Pilots' Associate.
Late FY 1988	Late FY 1988	Overhead image analysis system using artificial intelligence and supercomputers installed in an intelligence operational environment.

f. Explanation of Milestone Changes: (Delays due to contract negotiation)

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Project: #ST-11  
Program Element: #62301E  
USDR&E Mission Area: 530

Title: Intelligent Systems  
Title: Strategic Technology  
Budget Activity: 1. Technology Base

#### H. PROJECTS OVER \$7 MILLION IN FY 1987:

1. Project Description: The Intelligent Systems project is investigating fundamental capabilities for intelligent information processing in which computers can assist, advise, and/or relieve military personnel in complex decision-making tasks. This includes tasks which are tedious, dangerous, or rapidly changing. The specific objective of this research project is to advance the frontiers of the field of artificial intelligence (AI), thereby providing a foundation of scientific principles for the development of a next generation of software systems that can demonstrate intelligent behavior and which aid in the development of flexible software systems that show unique promise for solving complex military problems. To meet this objective, the research in this program explores new ways of computationally representing and using knowledge that permits symbolic reasoning tasks to be performed such that one would ascribe intelligence to a human who performed them. Research efforts include the discovery of new reasoning processes, knowledge acquisition and representation, image understanding, intelligent user interfaces, cooperative problem solving in distributed environments, fundamental architectures for expert systems, machine learning, the intelligent organization and management of knowledge bases, and new generation software. A new generation of software and systems evolution environments using artificial intelligence techniques are being developed to accelerate the software and systems development process.

#### 2. Program Accomplishments and Future Programs:

a. FY 1985 Accomplishments: An integrated software environment was produced for the evaluation, demonstration, and transfer of image understanding technology as applied to the automated cartography task in partnership with the Defense Mapping Agency. Natural language research in supporting complex queries for photointerpretation was extended by improving hierarchical representations in order to constrain search. A knowledge-based system for the interpretation of airport images, called SPAM, successfully demonstrated the use of spatial and structural constraint

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Title: Intelligent Systems  
Title: Strategic Technology  
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knowledge of airports to generate multiple plausible scene models. SPAM is a new approach to image understanding which integrates rule-based systems, spatial databases, and a collection of feature specific image analysis modules. Algorithm improvements for image understanding continue to increase the efficiency of low level feature analysis. An improved algorithm for visual stereo was developed that runs about two orders of magnitude faster than previous algorithms. In the areas of natural language processing, work on the knowledge representation system KL-TWO has permitted the first realistic attempts to integrate the reasoning associated with syntax, semantics, and discourse analysis. A prototype text understanding system, RESEARCHER, that accepts technical texts, organizes the information in a dynamic memory, and answers queries about the knowledge base has been demonstrated. A simulator and display system has been implemented which provides a three dimensional Newtonian model of the world that will provide the reactive environment for a series of machine learning experiments. A machine learning experiment, SOAR, has demonstrated a general learning mechanism known as chunking that allows computer programs to improve their performance wherever new problems are solved. Control structures which have significant problem domain knowledge were developed for supporting expert systems with flexible explanation facilities. A prototype system for automatic load balancing and reconfiguration of a distributed sensor network was completed. A knowledge based system for interpreting three-dimensional signal information was demonstrated using a blackboard control structure. A new approach to integrated programming environments based on a persistent object base was designed and a prototype developed. A prototype functional programming language with formal semantics to support machine intelligence assisted verification of specific formal properties was designed, initial prototype developed, and evaluation started. A prototype inferential programming model was developed.

b. FY 1986 Program: Research will focus on image understanding, basic schemes for problem solving and learning in AI, knowledge based processing, expert system tools, defense applications of AI, and distributed AI. In image understanding, the SPAM system is being expanded to analyze airport scenes with more complex spatial organizations. An improved image understanding algorithm for deriving the motion of a viewer is being implemented. The use of parallel algorithms is being

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### FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: #ST-11  
Program Element: #62301E  
USDR&E Mission Area: 530

Title: Intelligent Systems  
Title: Strategic Technology  
Budget Activity: 1. Technology Base

explored to improve the efficiency of image understanding algorithms. The SOAR software architecture is being used as a testbed for machine learning research. Technology is being developed for an abstraction-planning mechanism and a problem-space creation mechanism; capabilities will be demonstrated in a large task domain. A learning apprentice (LEAP) which assists and learns about the domain of Very Large Scale Integrated circuit design will demonstrate the ability to produce general rules from specific training examples. A text analysis system, RESEARCHER, is being extended to incrementally buildup hierarchical descriptions of organizations in order to address combinatorial problems that arise in developing dynamic memories. A new class of database management systems is being developed to provide capabilities for spatial and temporal data management as well as providing recursive query facilities. An expert system that utilizes an explanation process which is relatively easy to modify and extend is being designed. A resource management program that guides preparation of management plans for resource allocation using knowledge base technology is being implemented. An empirical analysis of a distributed control problem solving system is being conducted to better understand meta-level distributed control components for fault-diagnosis, load balancing, and organizational design. A new experimental software and systems evaluation environment will be designed, and new process models developed based on competitive selections.

c. FY 1987 Planned Program and Basis for FY 1987 Request: Algorithms for optical flow, stereo analysis, standard or stochastic regularization, and object recognition will be developed. Techniques will be extended for using rule-based methods for knowledge-based control of low level scene analysis in systems such as SPAM. Integration of multiple types of sensor data, including techniques such as trinocular stereo, will be explored. New theories of reflectance will be developed to enable programs to determine surface reflectance in spite of unknown illumination. The challenge of dynamically changing environments will force new theories to be developed for stereo matching and other intermediate computer vision techniques. The applicability of learning apprentice systems, such as LEAP, which directly assimilate new knowledge in the course of its assistance to a user will be investigated in several new domains such as robot construction. An elementary natural language interface is a planned enhancement for the SOAR problem solving and learning architecture as

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well as on determinations of the sufficiency of the chunking mechanism, demonstration of deliberate planning and analogical reasoning, and extension to real-time tasks. Research will be focused on developing techniques for designing software to improve the efficiency of building knowledge based systems. A major thrust will be to develop separate modules used for inference, control, and representation which can be used across multiple application domains. Development will also provide intelligent front-end tools to guide the user in constructing knowledge based systems. Systems that effectively couple the flexibility of intelligent systems with the principled structure and efficiency of database systems will be developed and applied to map interpretation problems. A generic distributed problem solving architecture that includes the control and data flow relationships among the meta-level control components will be developed. A new experimental software and systems evolution environment will be designed containing extensible subsystems for object management, knowledge representation, reasoning, transformation, specifications and user interfaces.

d. Program to Completion: The basic research program will continue to explore artificial intelligence problems that are of fundamental importance to DoD. Very difficult research areas such as commonsense reasoning, learning and discovery will begin to find limited application in more applied areas such as expert systems and natural language processing systems. The most promising of these will be explored further in the context of large scale systems as part of the strategic computing program, Project ST-10. Knowledge acquisition and knowledge representation will continue to be of great interest because of their importance to achieving the next evolutionary step in capabilities for applied artificial intelligence. Work will also continue in areas such as cooperative problem solving, reasoning with uncertainty, image understanding, expert systems, and natural language because of their overwhelming importance in solving critical military problems. Research in planning and user modeling will become ripe for exploitation in command and control domains. Research to develop methods for computers to discover knowledge and learn new rules will enable development of more robust expert systems. The structure and formalism of database technology will be merged with the powerful representation and control models used in artificial intelligence in order to produce knowledge management methods that efficiently support complex query processing and

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### FY 1987 RDT&E DESCRIPTIVE SUMMARY

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sharing of information among distributed processors. Significant advances in planning systems will result from discoveries in automated learning and discovery methods. Knowledge base representation advances will result in better query optimization methods for data access and in improved methods to represent goals used for planning systems. Research will continue to focus on those problems in intelligent data management that are of fundamental importance in developing large, distributed command and control systems, and ways will be found to effectively meld the benefits of flexible representations and reasoning abilities of knowledge based systems with the structure and efficiency of database systems. New experimental environments will be developed to support the development of new software and systems evolution process models. Knowledge representation, acquisition, and reuse techniques will be developed to support knowledge based rapid prototyping, production quality refinement, and evaluation. Strategic computing technology will be inserted using the new foundations for advanced distributed systems to increase functionality and performance.

#### e. Milestones:

Last Year's Reported Plan	Current Plan	Milestone
Early FY 1986	Early FY 1986	Demonstration of LEAP which will assist in and learn about VLSI circuit design.
Mid FY 1986	Mid FY 1986	Demonstrate SOAR's learning capability on additional tasks such as the NEOMYCIN or VLSI routing task.

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## FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: #ST-11  
Program Element: #A2301E  
USDR&E Mission Area: 530

Title: Intelligent Systems  
Title: Strategic Technology  
Budget Activity: 1. Technology Base

<u>Last Year's Reported Plan</u>	<u>Current Plan</u>	<u>Milestone</u>
Mid FY 1986	Mid FY 1986	Develop a knowledge-oriented database management system PROBE, and demonstrate key capabilities in storage structures, access methods and efficient query processing.
Mid FY 1986	Mid FY 1986	Develop a prototype expert system providing an architecture that allows it to explain the reasoning processes used to support query; such a system can be modified to extend to a new problem domain with relative ease.
	Late FY 1986	Demonstrate recovery from overgeneralization and learning by example in SOAR.
	Late FY 1986	Demonstrate an image understanding algorithm that determines motion without computing optical flow.
	Late FY 1986	SPAM's capability to analyze additional airport scenes possessing different spatial organizations will be demonstrated.
Early FY 1987	Early FY 1987	Demonstration of intelligent cartographic aid for determining map to image correspondence.

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### FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: #ST-11  
 Program Element: #62301E  
 USDR&E Mission Area: 530

Title: Intelligent Systems  
 Title: Strategic Technology  
 Budget Activity: 1. Technology Base

<u>Last Year's Reported Plan</u>	<u>Current Plan</u>	<u>Milestone</u>
	Mid FY 1987	Demonstrate SOAR's ability to do deliberate planning and analogical reasoning.
Mid FY 1987	Mid FY 1987	Demonstrate the dimensional information handling and knowledge processing capabilities of PROBE.
Mid FY 1987	Mid FY 1987	Demonstration of a system for generating programs in a specific domain from high-level specifications.
	Late FY 1987	Demonstrate the blackboard control architecture to implement control reasoning.
	Late FY 1987	Design of new generation experimental environment completed with initial prototype.
	Late FY 1988	Demonstrate that the SOAR architecture is capable of supporting the range of intelligent problem solving behaviors so far investigated in AI.
	Late FY 1988	Prototype new experimental environment applied to new process models.

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### FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project #ST-11  
Program Element: #A2301E  
USDR&E Mission Area: 530

Title: Intelligent Systems  
Title: Strategic Technology  
Budget Activity: 1. Technology Base

Last Year's  
Reported Plan      Current  
                                 Plan

#### Milestone

Late FY 1988      Demonstrate the explanation capability in BB1 showing the support of increasingly complex control plans.

f.      Explanation of Milestone Changes: None.

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FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: #ST-12  
Program Element: 62301E  
USDR&E Mission Area: 530

Title: Advanced Quantum Electro-Optics  
Title: Strategic Technology  
Budget Activity: 1. Technology Base

H. PROJECTS OVER \$7 MILLION IN FY 1987:

1. Project Description: The objective of the Advanced Quantum Electro-Optics project is to develop optical technologies to make possible a broad range of new military capabilities including ultra long range space imaging from the ground, space-based and airborne optical detection and imaging systems and long range, endo-atmospheric imaging systems. This new project, started in late FY85, will focus on developing advanced materials and techniques for increasing the spatial resolution of optical systems and the temporal resolution of optical and microwave systems. This includes work on computer generated holograms for efficient diffractive optics, non-linear optics for real time holography, advanced adaptive optics for atmospheric correction, matched-filter target detection and picosecond laser technology for precision measurements of material processes and ultrafast optoelectronics.

2. Program Accomplishments and Future Programs:

a. FY 1985 Accomplishments: A head start on this new project was initiated in late FY 1985 by using some of the residual funds in ST-03. A novel concept (by Itek) was funded to evaluate its feasibility for producing diffraction limited images through very severe turbulence while using low-quality optics. A novel concept using infrared focal plane arrays to improve infrared sensor survivability was also funded.

b. FY 1986 Program: In FY 1986, the work on developing new components and new techniques continues, and the design of a number of laboratory experiments as well as the test planning of field experiments are started. New components and techniques which can significantly improve the spatial resolution and/or temporal resolution of advanced imaging sensors and surveillance systems include holography, adaptive optics, large-aperture technology and picosecond laser technology. The computer generated hologram or diffractive optics technology developed in TT-05 project is being investigated to provide concepts for agile beam steering in conjunction with lasers being developed in TT-06 project and for mode matching of high power microwaves and/or optical sources to antennas for increased system sensitivity. The high power solid state lasers being developed in TT-06 project are being evaluated as a source to provide possible x-ray radiation for submicron lithography to extend the holographic diffractive

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: #ST-12  
Program Element: 62301E  
USDR&E Mission Area: 530

Title: Advanced Quantum Electro-Optics  
Title: Strategic Technology  
Budget Activity: 1. Technology Base

optics techniques to the visible wavelengths. In advanced adaptive optics, techniques are being developed to increase the number of photons available for the wavefront sensor for correcting atmospheric turbulence to achieve near diffraction-limited images of space objects from the ground. A new class large array deformable mirror using a single scanning electron beam or multiple electron beams for rapid and accurate control of the mirror surface is being developed for possible application in correcting short wavelength lasers over large optical beam diameters. New imaging sensor concepts such as the Itek concept are being developed to achieve the high spatial resolution associated with very large apertures. A new class of F center materials is being developed to provide tunable laser action in the visible region. This will be exploited to produce picosecond laser pulses of sufficient energy for a variety of applications including materials characterization and processing, precision ranging and remote sensing of the atmosphere. Concepts that use the picosecond laser pulses to do fast optoelectronic switching to generate very fast risetime microwaves for a variety of sensor and anti-sensor applications will be developed and evaluated.

In FY 1986, the design of laboratory experiments to verify the Itek concept has been started. Also, test plans are being formulated to collect satellite signature data.

c. FY 1987 Planned Program and Basis for FY 1987 Request: In FY 1987, this project will build on recent breakthroughs in atmospheric compensation technologies, as well as on the component technology development started in FY 1986. Methods of active space imaging will be developed and coupled with ground based telescope concepts (based on e.g., the Itek concept) will be used to enhance the signal to noise in the wavefront sensor to fully compensate for the effects of atmospheric turbulence. Once developed over the next several years, this technology will be used to support systems which could provide near diffraction limited images of space objects.

This effort together with the work on spatial filters for efficient target detection amongst clutter, the work on optical processing of images and multidimensional signals (from a number of sensors), the work on efficient algorithms for scene to scene correlation and the work on picosecond laser technology can lead to significant capability in detection and imaging of low observable targets in clutter.

# FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: #ST-12  
 Program Element: 62301E  
 USDR&E Mission Area: 530

Title: Advanced Quantum Electro-Optics  
 Title: Strategic Technology  
 Budget Activity: 1. Technology Base

In FY 1987, work on the laboratory experiments will continue. A number of field experiments to demonstrate the new capabilities as described above will be started.

d. Program to Completion: Major optical component development will be completed during FY 1987. Laboratory experiments to provide concept feasibility demonstrations will be conducted in FY 1988. Field experiments will be conducted jointly with the military services. These technologies will then be transitioned to the military services for further development.

## e. Milestones:

<u>Last Year's Reported Plan</u>	<u>Current Plan</u>	<u>Milestone</u>
Late FY 1987	Late FY 1987	Linear and Nonlinear Optical Component Development and Concept Definition
Late FY 1988	Late FY 1988	Laboratory feasibility demonstration experiments.
Late FY 1990	Late FY 1990	Field experiments to verify predictions of models.

## f. Explanation of Milestone Changes: No change.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: #ST-13

Program Element: #62310E

USDR&E Mission Area: 530

Title: Strategic Aircraft and Cruise Missile Defense

Title: Strategic Technology

Budget Activity: 1. Technology Base

H. PROJECTS OVER \$7 MILLION IN FY 1987:

1. Project Description: This project consolidates efforts previously funded under project ST-1. The Strategic Aircraft and Cruise Missile Defense (SACM) program objectives are to identify and develop techniques for surveillance of aircraft and cruise missiles. The potential threat vehicles, primarily aircraft and cruise missiles, also include generic targets such as satellites and theater mobile targets. Mission functions addressed include surveillance (acquisition, track, identification), targeting and kill assessment. The SACM Program will develop system concepts, associated technologies, and an architecture to provide the building blocks for advanced strategic surveillance capability. The goal is to achieve order-of-magnitude sensitivity improvements compared to existing surveillance systems. A two phase program is planned. In the first phase, promising new sensor concepts will be identified and analyzed. An architecture task will also be initiated in Phase I to develop the framework for evaluating multiple phenomenology sensor systems. The architecture efforts would include tasks for scenario and model development for evaluating overall system concepts; threat development/projection; concepts for energy spectrum (sensor) management; and, concepts for C<sup>3</sup> and data fusion. This new initiative will include efforts such as major system studies to developments of key technology components for advanced high speed processors. The program will be based on advanced technologies such as TEAL RUBY, HI CAMP, and Long Range Interceptor Experiment.

2. Program Accomplishments and Future Programs: The SACM program resulted from a DARPA sponsored surveillance architecture effort during FY 1983 and FY 1984 which was accomplished in house with other government agency support. This effort reviewed all the major advanced surveillance technologies that could support future surveillance system needs. The specific targets included in SACM extend the President's Strategic Defense Initiative (SDI) for a U.S. defensive shield against ballistic missiles to cover air breathing target.. The program will evaluate all advanced surveillance concepts and platforms and how to integrate them. During FY 1984, the surveillance architecture was completed and new ideas solicited. A program structure was established to run the program.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: #ST-13

Program Element: #62301E

USDR&E Mission Area: 530

Title: Strategic Air and Cruise Missile Defense  
Title: Strategic Technology  
Budget Activity: 1. Technology Base

a. FY 1985 Accomplishments: The Strategic Aircraft and Cruise Missile Defense (SACM) Phase I effort started in FY 1985 with evaluation of new ideas/proposals. Architectural models on the primary mission of Continental United States (CONUS) air defense and fleet defense and other secondary missions such as theater surveillance and advanced targeting were initiated. System concepts and new techniques of traditional surveillance concepts were proposed and evaluated. Other activities included development of comparative tools and establishment of a technical steering committee. Two of the specific component and system areas selected for development are advanced array processors and hybrid bistatic radar (HBR) concept analysis. The advanced arrays for target detection will be developed and the HBR system engineering will be performed for possible demonstrations in the late 1980's including distributed aperture radar experiment planning and utility assessment. Evaluation panels reviewed 107 white papers, selected 57 for resubmission as proposals and subsequently recommended 25 proposals for funding.

b. FY 1986 Program: The SACM Phase I studies, initiated in FY 1985, of new innovative techniques and system concepts will be completed with the most promising techniques selected for further technology and concept development. These systems will also be evaluated using the architectural mission models to iterate the initial system concepts into the most effective integrated network to achieve significantly improved surveillance capability. The advanced ultra high performance Large Scale Integrated (LSI) chip will be developed in small test arrays and the demonstration and measurement test program for the HBR program will be developed. The HBR signal processor with antenna and receiver test articles will be developed for target detection.

c. FY 1987 Planned Program and Basis for FY 1987 Request: Investigation of innovative techniques and system concepts selected for further technology and concept development in FY 1986 will continue. Results from the demonstration and measurement test portion of the HBR program will be documented and evaluated. Performance of ultra high performance LSI chip test arrays will be measured. Initial bread boarding of components for innovative concepts and techniques will occur and system designs will be refined.

d. Program to Completion: An advanced surveillance sensors architecture will be developed. The high risk, new innovative surveillance technologies will be developed and tested.

# FY 1987 RDT&E DESCRIPTIVE SUMMARY

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 Program Element: #62301E  
 USDR&E Mission Area: 530

e. (U) Milestones:

Last Year's Reported Plan	Current Plan	Milestones	
Mid FY 1985	Mid FY 1986	Initiate architectural model development	
Late FY 1985	Late FY 1986	Sensor concepts/technology development	
Early FY 1986	Late FY 1986	Select Phase II concepts and technologies	
Mid FY 1986	Late FY 1986	Initial SACM concept evaluation	

f. Explanation of Milestone Changes: Budget reductions and competitive procurement activities in FY 1985 delayed initiation of Phase I architectural model development and follow-on Phase II efforts by 4 months.

# FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #62702E  
USDR&F Mission Area: 530

Title: Tactical Technology  
Budget Activity: 1. Technology Base

## A. RESOURCES: (\$ in Thousands)

Project Number	Title	FY 1985 Actual	FY 1986 Estimate	FY 1987 Estimate	FY 1988 Estimate	Additional to Completion	Total Estimated Costs
	TOTAL FOR PROGRAM ELEMENT	99,042*	94,250*	114,000*	117,000*	Continuing	N/A
TT-3	Naval Warfare	32,492	26,510	12,490	12,300	Continuing	N/A
TT-4	Advanced Armor Technology	7,050	7,557	11,970	11,200	Continuing	N/A
TT-5	Target Acquisition and Weapons Technology	36,281	46,518	56,340	57,450	Continuing	N/A
TT-6	Tactical Directed Energy Technology	0	5,630	19,500	24,050	Continuing	N/A

\* Total includes classified projects not identified herein.

B. BRIEF DESCRIPTION OF ELEMENT AND MISSION NEED: This program element is dedicated to the advancement of concepts and technologies that will serve as the basis for the development of the next generation of tactical systems. The program goal is to advance non-nuclear, tactical, combat capabilities to counter the expanding tactical threat with emphasis on high payoffs, reasonable costs, and realistic manpower constraints. The major development objectives are: (1) improving target acquisition and engagement technology; (2) advancing fire control, seeker, and command and control technology; (3) advancing warhead, munition and propulsion technology; (4) improving armor technology; and (5) enhancing ocean surveillance targeting and control technologies.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #62702E  
USDR&E Mission Area: 530

Title: Tactical Technology  
Budget Activity: 1. Technology Base

C. COMPARISON WITH FY 1986 DESCRIPTIVE SUMMARY: The total funding for FY 1986 is \$7.75 million less than the amount that was requested for that fiscal year in the FY 1986 Descriptive Summary. This reduction is the net effect of the following: (1) A reduction in the Naval Warfare project, due primarily to a reduction in the Mini-GPS Receiver program. (2) an increase in the Advanced Armor Technology project caused by initiation of a new Armor/Anti-Armor program and transfer of the Advanced Warhead Technology program from the Target Acquisition and Weapons Technology project. (3) An increase in the Target Acquisition and Weapons Technology project due to an increase in the Millimeter Wave Autonomous Sensor program, transfer of the Acoustic Charge Transport program from Project ST-7, Special Applications Technology (which is being terminated), increases in the Air Defense Technology and Infrared Binary Optics programs, and start up of the Hemispherical Resonator Gyro program, all of which offset the transfer of the Advanced Warhead Technology program described above. (4) The amount requested for the Tactical Directed Energy Technology project decreased because some work that was anticipated would be performed in FY 1986 was started earlier using residual funds from Project ST-3, High Energy Laser Technology (which is being terminated).

The total funding requested for FY 1987 is \$16 million less than the amount requested for that fiscal year in the FY 1986 Descriptive Summary. This was the result of reductions in the Naval Warfare and Tactical Directed Energy Technology projects, partially offset by increases in the Advanced Armor Technology and Target Acquisition and Weapons Technology projects. The decrease in the Naval Warfare project was caused by the forthcoming transfer of the ARIADNE program to the Navy as well as a general funding reduction mandated by the Secretary of Defense. The Advanced Warhead Technology program was transferred from the Target Acquisition and Weapons Technology project and increased resources are being requested for that program. The increase in the Target Acquisition and Weapons Technology project is due to the same factors described above relating to the increase in the FY 1986 funding for this project. The decrease in the Tactical Directed Energy Technology project is due to the early accomplishment of efforts related to free electron laser physics.

D. OTHER APPROPRIATION FUNDS: None.

F. RELATED ACTIVITIES: Overall coordination of efforts is maintained with representatives of the Office of the Under Secretary of Defense for Research and Engineering, the offices of the service

FY 1987 RDT&E DESCRIPTIVE SUMMARY

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Title: Tactical Technology  
Budget Activity: 1. Technology Base

assistant secretaries responsible for research and advanced development, and the corresponding service headquarters staff offices. In addition, direct coordination of activities with appropriate service laboratories is maintained through means such as technical interchange meetings and conferences.

Specific Naval Warfare project coordination mechanisms are as follows: The Systolic Array Processor program is coordinated through the Space and Naval Warfare Systems Command (SPAWAR) and the Naval Sea Systems Command (NAVSEA) and a Memorandum of Understanding (MOU) has been signed with these organizations. Similarly, the ARIADNE Program is also coordinated with SPAWAR which is jointly sponsoring the development of certain aspects of the required technology base. The Advanced Conformal Submarine Acoustic Sensor program is being pursued as a joint venture by DARPA, the Office of Naval Research, and the Office of the Chief of Naval Operations (Submarine Warfare) and an existing Memorandum of Agreement (MOA) governs the effort. The Mini-GPS Receiver Program is being run in coordination with the Global Positioning System Special Project Office and with support from the United States Marine Corps.

The Advanced Armor Technology project activities are coordinated with the Army Armament Research and Development Center, Army Ballistic Research Laboratory, Army Materials Technology Laboratory, Naval Surface Weapons Center (White Oak), and Naval Surface Weapons Center (Dahlgren). The Advanced Warhead Technology program includes the jointly funded Penetration Augmented Munition (PAM) development with the Army.

In the Target Acquisition and Weapons Technology project, the Surveillance Radar program is a joint development with the Army with which the Marine Corps maintains a close liaison. In the Advanced Ramjet Munition Technology program, the Army is jointly funding the development of the ramrod-powered, rod penetrator munition (RAMROD) and the 40 mm Tubular Projectile. The Ramjet Combustion Phenomenology Study is a joint effort with the Naval Weapons Center, China Lake and the Army Ballistics Research Laboratory. The Boron Solid Fuel Ramjet Flight demonstration is a jointly funded project with the Navy. The Advanced Warhead Technology program includes the jointly funded Penetration Augmented Munition (PAM) development with the Army. The Autonomous Infrared Sensor Technology program and the Millimeter Wave Sensor program are coordinated within the three services through the Joint Deputies for Laboratories and under the auspices of the Advanced Target Recognizer Working Group. The Acoustic Charge Transport program is related to programs of the Air Force Rome Air Development Center. The Uncooled Sensor program is jointly funded with the Army Night Vision and Electro-optical Laboratory and the Army Missile Command. DARPA is

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also an active member of the DoD Anti-Armor Master Plan Steering Group and Working Group. The Small Unit Technology (SUT) program is fully coordinated with Office of the Secretary of Defense/Command, Control, Communications and Intelligence/Special Operations Special Technology Program (OSD/C I/SOSTP), with the Joint Special Operations Agency (JSOA) and with the Services. Several of the projects under SUT, e.g., Advanced Technology Tactical Transport (AT<sup>3</sup>) aircraft, are jointly funded.

Plans for the new Tactical Directed Energy Technology project are coordinated through frequent technical interchange meetings with representatives from the three Services' tactical directed energy programs. Technology developments under the Strategic Defense Initiative Organization are periodically reviewed to identify possible opportunities for exploitation.

F. WORK PERFORMED BY: Approximately 85% of the work of the Naval Warfare project is carried out by industry and 15% by DoD in-house agencies. Industrial contractors involved in research programs under this project are: Bolt, Beranek and Newman, Inc., Arlington, Virginia and Cambridge, Massachusetts; AMRON Corporation, Fairfax, Virginia; McDonnell-Douglas Astronautics Company, Huntington Beach, California; General Dynamics Corporation, San Diego, California; Tetra-Tech Inc., Arlington, Virginia and Pasadena, California; Rockwell International, Anaheim, California; and Magnavox Corporation, Torrance, California. The in-house effort is performed by the Naval Ocean Systems Center, San Diego, California; the Naval Underwater Systems Center, New London, Connecticut and Newport, Rhode Island; the Naval Ship Research and Development Center, Carderock and Annapolis, Maryland; the Naval Research Laboratory, Washington, D.C.; and the Office of Naval Research, Washington, D.C.

59% of the Advanced Armor Technology project and Target Acquisition and Weapons Technology project work is performed by industry, 36% was performed by a Federal Contract Research and Development Center, while universities account for 1%; the remaining 4% is performed in-house by government laboratories. The performers are the Johns Hopkins University, Applied Physics Laboratory, Adelphi, Maryland; Arizona State University, Tempe, Arizona; University of Florida, Gainesville, Florida; University of Massachusetts, Amherst, Massachusetts; Purdue University, West Lafayette, Indiana; Systems Planning Corporation, Arlington, Virginia; Rockwell International Corporation, Los Angeles, California; Massachusetts Institute of Technology Lincoln Laboratory, Cambridge, Massachusetts; the Environmental Research Institute of Michigan (ERIM), Ann Arbor, Michigan; Martin Marietta Corporation, Orlando, Florida; Westinghouse Corporation, Baltimore, Maryland; Goodyear Aerospace, Litchfield Park, Arizona;

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Interactive ITV, Arlington, Virginia; CACI, Arlington, Virginia; Perceptronics, Woodland Hills, California; Scaled Composites, Mojave, California; Honeywell, Bloomington, Minnesota; General Motors Corp., Santa Barbara, California; Boeing Aircraft Co., Seattle, Washington; Science Applications Inc., La Jolla, California; Chemical Systems Division of United Technologies, San Jose, California; BDM Corporation, McLean, Virginia; and U.S. Army Ballistics Research Laboratory, Aberdeen Proving Ground, Maryland; Naval Weapons Center, China Lake, California; Naval Surface Weapons Center, Dahlgren, Virginia; Naval Research Laboratory, Washington, D.C.; and Los Alamos National Laboratory, Los Alamos, California.

Initially, the new Tactical Directed Technology project work is based on the advanced research and development activities of in-house Government Laboratories. As the project progresses, it is anticipated that 50% of the project work will be conducted by industry, 40% by in-house Government Laboratories and 10% by Universities. At present, the top performers are Lawrence Livermore National Laboratory, Livermore, California; Los Alamos National Laboratory, Los Alamos, New Mexico; Naval Research Laboratory, Washington, D.C.; TRW Corporation, El Segundo, California and Sanders Associates, Nashua, New Hampshire.

G. PROJECTS LESS THAN \$7 MILLION IN FY 1987: Not applicable.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: #TT-3  
Program Element: #62702E  
USDR&E Mission Area: 530

Title: Naval Warfare  
Title: Tactical Technology  
Budget Activity: 1. Technology Base

H. PROJECTS OVER \$7 MILLION IN FY 1987:

1. Project Description: The objective of the Naval Warfare project is to investigate new technologies and system concepts which would significantly enhance the maintenance of effective surveillance, targeting, and control of surface and subsurface ocean areas. The earlier emphasis on surveillance of the Soviet submarine forces has been expanded to address a wider range of ocean warfare issues for both surface and submerged targets and the development of more capable weapon system concepts to meet the expanding Soviet threat. The project emphasizes the performance of key experiments validating critical technology elements or system concepts prior to Navy transition. Major initiatives currently being pursued include: (1) ARIADNE (TIARA), a program investigating the application of fiber optic cabling and telemetry techniques for strategic or tactical undersea surveillance. (2) Advanced Conformal Submarine Acoustic Sonar (ACSAS), a program developing a new high gain submarine sonar to be designed as part of the ship's hull. (3) Integrated Non-acoustic Anti-submarine Warfare (ASW), a program investigating several specific sensor approaches, and also the integration with conventional acoustic techniques to achieve greater overall effectiveness. (4) Mini-Global Positioning Satellite (GPS) Receiver, a program developing the circuit technology for a hand held, cigarette package size, Global Position System Receiver. (5) Systolic Array Processor, a program developing novel digital architectures needed for processing the signals from advanced acoustic sensors. (6) Acoustic ASW Technology, an umbrella program incorporating a variety of tasks in acoustic sensors and systems. In addition, through 1985 this project included the Advanced Undersea Vehicle (AUV) (TIARA) program which has transitioned in FY 1986 to PE 63226E.

2. Program Accomplishments and Future Programs:

a. FY 1985 Accomplishments:

ARIADNE: Major prototype undersea hardware developments were completed in FY 1985. Low-loss, wet-mateable, single mode fiber-optic connectors were developed, and tested successfully through repeated mate/demate cycles under 10,000 psi sea water at losses consistently less than 1/2 dB. This connector is now in production. Lightweight, single-mode undersea fiber-optic cables were developed and tested, and the first 250 km of this cable are now being produced at a cost of \$1.79 per meter. Working breadboards

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Title: Naval Warfare  
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have successfully demonstrated the detailed functionality of the electronic and optical designs. Prototypes are now in the final stages of fabrication. Multiple mock-ups of ARIADNE nodes have been successfully deployed at sea. A fully deployed mechanical model was visually inspected at a depth of 1,000 feet by the Deep Search and Rescue Vehicle (DSRV). Multiple mechanical models of this successful node design, connected by actual fiber-optic cables, are now being used to perform at-sea rehearsals of ARIADNE string deployment. An initial data recording and monitoring system to support the FY 1986 ARIADNE sea tests has been designed, and fabrication is nearing completion.

Advanced Conformal Submarine Acoustic Sonar (ACSAS): Analysis was completed of turbulent boundary layer noise experimental data obtained during the summer and fall of CY 1984. The counterpart structural noise issue was examined in a set of experiments carried out on specially made steel cylinders: The data will be analyzed in FY 1986. Small, scaled versions of the array structure itself were built and tested, as were several variants of the basic hydrophone. Major program documentation was prepared, reviewed and distributed: it records the logic underlying the ACSAS design. The design was completed of a one-quarter scale model submarine incorporating ACSAS' features, and fabrication was started at the Oak Ridge National Laboratory.

Integrated Non-Acoustic Anti-Submarine Warfare (ASW): An estimate was formulated and furnished to the Central Intelligence Agency and Navy (OP-95) of the utility in submarine detection/localization. The estimate's math model was verified using data from experiments.

An effort was initiated to identify possible synergisms between various acoustic and non-acoustic ASW techniques. This effort will be completed or transitioned to the Navy in FY 1986.

A program was initiated to evaluate Anti-submarine Warfare (ASW) search and localization applications.

Mini-Global Positioning Satellite (GPS) Receiver: Mini-GPS Receiver is a 30-month effort started in FY 1985 to develop a cigarette pack sized GPS receiver with full function capability. This will be the first development incorporating extensive Monolithic Microwave Integrated Circuits (MMIC).

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Systolic Array Processor: A detailed simulation of the CHIMERA processor was completed in the laboratory. The demonstrations were performed using data from experiments carried out by the Navy in 1984. Sixty percent of the circuit boards and the processor chassis were completed and passed preliminary bench tests.

Acoustic ASW Technology: The following tasks were undertaken: low frequency seismic adjunct study, performance potential of long vertical arrays, tube array resonance experiments, and expert system applications to automatic detection and classification. In addition, funds were expended to sponsor the annual joint Navy/DARPA Underwater Surveillance Symposium.

Advanced Undersea Vehicle (AUV): Laboratory testing was completed and simulations of selected AUV missions were run incorporating the brassboard hardware. A technology development plan was completed identifying potential demonstration program objectives. This program has been transferred to PE 63226E.

b. FY 1986 Program:

ARIADNE: The prototype hardware developed over the past few years will be integrated and tested at-sea as an initial small-scale ARIADNE system. Conduct of these engineering sea tests will conclude DARPA's participation in Project ARIADNE sponsorship, with complete transfer to the Navy at the start of FY 1987.

Advanced Conformal Submarine Acoustic Sonar (ACSAS): The data from the cylinder experiments in structural acoustics will be analyzed. The one-quarter scale model will be completed and delivered to the test site. A full suite of structural sensors, data telemetry modules, and data recording equipments will be installed and tested in the model. One or more shock tests will be conducted on acoustic array support panels to confirm that they meet structural strength requirements for submarine use. A study will be initiated to define the inboard processing requirements for the full ACSAS arrays. The study will address general needs and provide the basis for a more advanced study to be conducted during follow-on development stages.

Integrated Non-acoustic Anti-submarine Warfare (ASW): The integrated ASW study will be completed and a report promulgated. A detailed design study and associated ground truth experiments will be completed.

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Mini-Global Positioning Satellite (GPS) Receiver: A breadboard will be evaluated before proceeding with the full brassboard construction. Contracts will also be awarded to explore the feasibility of using this technology to guide 155 mm rounds.

Systolic Array Processor: The CHIMERA processor will be completed and delivered to the Navy for sea trial.

Acoustic Anti-submarine Warfare (ASW) Technology: The tasks initiated in FY 1985 will be completed. New tasks will be formulated, focussing on the Arctic.

c. FY 1987 Planned Program and Basis for FY 1987 Request:

ARIADNE: Not applicable: transfer to full Navy sponsorship will be completed in FY 1986.

Advanced Conformal Submarine Acoustic Sonar (ACSAS): A series of pop-up tests will be conducted to validate the array's ability to reject noise components. The control of hull borne noise will also be demonstrated in the scale model. Far field acoustic testing will be conducted to define the impact that the support structure and hull have on the acoustic performance of the array. As required, acoustic damping material may be added to the underside of the array to achieve the proper performance. The full data analysis will be completed and the results published. This will represent that final validation of the ACSAS design. At the end of FY 1987 the transition to the Navy for full Advanced Development will occur. All documentation will be completed and forwarded.

Integrated Non-acoustic ASW: Building of the experiment will be initiated. Exploration of non-conventional signal processing algorithms will continue utilizing real data.

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Mini-Global Positioning Satellite (GPS) Receiver: The brassboard will be completed in the summer of 1987. The Marine Corps will be paralleling the DARPA effort with an engineering development model (EDM) whose specifications will begin after the brassboard has been demonstrated: it will use the DARPA chip set. An experiment is expected to start in FY 1987 to demonstrate the ability to guide 155 mm rounds.

Systolic Array Processor: Not applicable. This program will be completed in FY 1986 with delivery of the CHIMERA processor.

Acoustic Anti-submarine Warfare (ASW) Technology: This is a continuing technology development program.

## d. Program to Completion:

### e. Milestones:

<u>Last Year's Reported Plan</u>	<u>Current Plan</u>	<u>Milestones</u>
ARIADNE:		
Late FY 1985	Late FY 1986	Development of fiber-optic telemetry link
Late FY 1987	Late FY 1987	Initial system demonstration
Advanced Conformal Submarine Acoustic Sonar (ACSAS):		
Mid FY 1985	Mid FY 1986	1/4 scale tests
Mid FY 1986	Mid FY 1987	Shock testing
Late FY 1986	Mid FY 1987	system tests

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<u>Last Year's Reported Plan</u>	<u>Current Plan</u>	<u>Milestones</u>
Advanced Conformal Submarine Acoustic Sonar (ACSAS):		
N/A	Late FY 1987	Transition to Navy
Integrated Non-Acoustic Anti-submarine Warfare (ASW):		
End FY 1985	Mid FY 1986	Complete integrated ASW study
Mid FY 1986	Late FY 1986	Complete airborne LIDAR experiment design
Mini-Global Positioning Satellite (GPS) Receiver:		
Mid FY 1985	Mid FY 1986	Initiate brassboard
Mid FY 1986	Mid FY 1987	Complete brassboard
N/A	Mid FY 1987	Initiate munitions experiment
Systolic Array Processing:		
N/A	Late FY 1986	Delivery of processor to Navy
Acoustic Anti-submarine Warfare (ASW) Technology:		
N/A	Late FY 1986	Large vertical array performance assessment

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Reported Plan

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## Milestones

N/A

Mid FY 1986

Tube resonance assessment

f. Explanation of Milestone Changes: ARIADNE (TIARA): Difficulties in large scale integrated circuit development have caused a one quarter slip in delivery of the prototype.

Integrated Non-Acoustic Anti-submarine Warfare (ASW): Completion of integrated ASW has been delayed because of the complexity of the problem, and contractual delays in initiating the effort.

Mini-Global Positioning Satellite (GPS) Receiver: A one year delay was encountered in awarding the development contracts.

Systolic Array Processor: The program was redefined.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: #TT-04  
Program Element: #62702E  
USDR&E Mission Area: 530

Title: Advanced Armor Technology  
Title: Tactical Technology  
Budget Activity: Technology Base

H. PROJECTS OVER \$7 MILLION IN FY 1987:

1. Project Description: The overall objectives of this project are to accelerate for critical defense needs: development of advanced armor systems for lightweight combat vehicles and future main battle tanks, and development of anti-armor munitions such as kinetic energy penetrators, shaped charge warheads, and explosively formed penetrators. The key elements include: design and evaluation of advanced structural and applique armors; fundamental studies of materials behavior and target/penetrator interactions; development and evaluation of high performance materials; and exploratory studies of new armor and penetrator concepts. The Advanced Armor Technology Program has as its key ingredients, support of research on: lightweight armor for protection against small arms threats, including studies of ceramic composites and special steel laminates, and emphasizing performance and producibility optimization; mass efficient heavy armor for protection against kinetic energy and shaped charge threats, including studies on phenomenology and scaling of penetrator/target interactions and ceramic composite armor systems; advanced shaped charge research including studies on jet control by liner material variation, an integral jet slug concept, and development of high performance depleted uranium alloys; and kinetic energy penetrator studies on powder metallurgy tungsten and depleted uranium alloys, multi-stage projectiles and hypervelocity penetrators. The Advanced Warhead Technology program features the joint DARPA/Army development of the Penetration Augmented Munition (PAM) as the application of the generic Multi-stage Conventional Munition (MCM) technology. MCMs deposit 30-50% of their total explosive energy into a structure as opposed to today's conventional munitions that deposit 6-8%. The 1985 Defense Science Board Summer Study strongly recommended a greater U.S. research and development effort involving armor and advanced munitions. To respond to this recommendation, a new Armor/Anti-Armor program is being initiated to stimulate innovative concepts by involving a broad industrial and university base. The objectives are to generate new concepts and ideas; develop the fundamental physics and computational techniques necessary for new armors and anti-armor devices; and develop the experimental capabilities to fabricate and independently test the most promising concepts. The theoretical effort will build on recent advances in understanding and modelling impact physics of strategic reentry vehicles.

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Program Element: #62702E

USDR&E Mission Area: 530

Title: Advanced Armor Technology

Title: Tactical Technology

Budget Activity: Technology Base

2. Program Accomplishments and Future Programs:

a. FY 1985 Accomplishments:

FY 1985 Advanced Armor Technology program accomplishments included the following: fundamental studies of projectile defeat mechanisms were carried out to obtain data critical to the design of improved armor systems to defeat both kinetic energy (KE) penetrators and shaped charge jets; lightweight armor systems to defeat small caliber projectiles were designed and successfully tested; and several studies relating to armor fabrication problems were started. Preliminary performance bounds for advanced KE penetrators were established and work was initiated to improve computer modelling capabilities for various penetrator/target interactions. Several studies involving the development of improved materials for anti-armor munitions were continued, and required materials handling and processing facilities for carrying out penetrator materials development work were established. Work was begun on ballistic evaluation of special steel laminated armor structures that have high hardness and penetration resistance.

In the Advanced Warhead Technology program, the preliminary design was completed for the Penetration Augmented Munition (PAM). The technology for scaling up the PAM's forward and main charges, firing, timing, and propulsion components was conducted by computerized models and actual experiments. In addition, design and modelling efforts for the Adaptive Warhead (a target-sensing and multi-point initiating shaped charge) were begun and completed, modelling efforts for the Distributed Explosive Charge with Afterburning were completed, and design efforts for the High Explosive Anti-Tank Rifle grenade were initiated.

b. FY 1986 Program:

In FY 1986, fundamental armor performance issues relating to defeat mechanisms are being addressed in the Advanced Armor Technology program and lightweight armor design and evaluation efforts directed KE penetrators is continuing and penetrator performance potential is being assessed at very high impact toward establishing performance capabilities against advanced small arms threats. Materials development

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efforts are continuing on a broad front and a performance database for various shaped charge liners is being established. Exploratory research to evaluate a new warhead concept is being completed and a similar study involving a penetrator is being continued. Armor fabrication studies are continuing and two different armor investigations are underway.

Efforts in the Advanced Warhead Technology program continue with full-scale experimental Penetration Augmented Munition (PAM) firings, Distributed Explosive Charge with Afterburning (DEC-A) test measurements and full-scale firing of the High Explosive Anti-Tank Rifle (HEATR) grenade demonstration. Evaluation of multiple approaches to the Adaptive Warhead are being evaluated; and selected ones conceptually modelled.

The major new Armor/Anti-Armor program that is beginning in FY 1986 is developing the technology for significant advances in armor protection and armor defeat. This broad research and demonstration effort is identifying fundamental mechanisms and phenomenology of advanced armor; developing mathematical models and measuring techniques to characterize the equation-of-state of materials at high strain rates; developing advanced passive and active armor techniques and making significant advances in armor defeat mechanisms, chemical and kinetic energy hypervelocity munitions, lightweight materials, and hybrid systems. The new initiatives in armor defeat build on recent advances in the DARPA millimeter wave infrared sensor (Project TT-05) and hypervelocity electromagnetic gun (Strategic Defense Initiative Organization Project Element No. 63222D) programs. In these programs, a new family of low cost terminal homing munitions is being demonstrated that is compatible with conventional and hypervelocity electromagnetic launch mechanisms.

c. FY 1987 Planned Program and Basis for 1987 Request:

Under the Advanced Armor Technology program, the performance of applique armors will be demonstrated in full-scale tests and the relative merits of various armor fabrication methods will be established. Research will be continued on new advanced materials for lightweight armor. Shaped charge liners fabricated using powder metallurgy techniques will be evaluated. Materials development studies will be continued, with increasing emphasis on test demonstrations. Work on advanced KE penetrators will be

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completed and large caliber full-scale tests are anticipated.

In the Advanced Warhead Technology Program, efforts will continue to explore new warhead technologies and related components. The PAM, Distributed Explosive Charge with Afterburning, and the High Explosive Anti-Tank Rifle will be transitioned to the Services as appropriate.

In the Armor/Anti-Armor Program, efforts will continue to generate new concepts and ideas; develop the fundamental physics and computational techniques necessary for new armors and anti-armor devices; develop the experimental capabilities to fabricate and independently test the most promising concepts; and develop a detailed modelling and predictive capability for future armors and anti-armor devices. Revolutionary new concepts in armor will be fabricated and tested. New concepts and innovative shaped charge materials and concepts will be tested for significantly enhanced penetration.

d. Program to Completion:

In the Advanced Armor Technology program, the emphasis will be on processing and performance optimization of those armor and penetrator materials which show outstanding promise. Theoretical modelling of target/penetrator interactions will emphasize mechanics/materials modelling aimed at providing a rationale for systems development. The results of the research will be transitioned to the Army and Marine Corps for systems demonstration. This program is expected to continue in subsequent years as well, with specific objectives evolving to address emerging challenges in this critical technology area. Specific emphasis will be on low cost new materials and materials design concepts for both armor and penetrators.

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The Armor/Anti-Armor program: Following the initial development of advanced computational models of hypervelocity impact phenomena, techniques will be developed to assist in armor and kinetic energy penetrator selection, evaluation and design. Selected near term demonstrations of advanced kinetic energy penetrators and shaped charges will be performed as advances are achieved in the fundamental technology. Specifically, impact phenomena will be investigated theoretically and experimentally at velocity regimes considerably higher than those achieved by conventional chemically propelled anti-armor projectiles (currently 1.2 km/sec). New materials and projectiles will be evaluated using advanced propulsion techniques. Their performance will be evaluated against conventional and advanced armors.

## e. Milestones:

Last Year's  
 Reported Plan

Current  
 Plan

## Milestones

### Advanced Armor Technology Program:

--	Mid FY 1986	Demonstrate improved ballistic performance of low cost composite armor and newly developed materials.
--	Late FY 1986	Demonstrate improved ballistic performance of advanced metal laminate armors.
--	Late FY 1986	Demonstrate ability to rapidly solidify advanced alloys having improved mechanical properties.
--	Late FY 1986	Demonstrate improved properties and performance of heavy-metal alloys for penetrator applications.

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Last Year's  
 Reported Plan

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## Milestones

### Advanced Armor Technology Program:

--	Mid FY 1987	Demonstrate improved ballistic performance of composite armor for light-weight combat vehicles.
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### Advanced Warhead Technology Program:

--	Late FY 1986	High Explosive Anti-tank Rifle (HEATR) grenade demonstrated.
Late FY 1986	Late FY 1987	Distributed Explosive Charge with Afterburning demonstrations.
Late FY 1986	Late FY 1987	HEATR transition to the Services.

### Armor/Anti-Armor Program:

--	Late FY 1986	Identification of mechanisms and phenomenology of advanced armor characterization of equation-of-state materials at high strain rates; development of advanced passive and active armor techniques.
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Title: Advanced Armor Technology  
Title: Tactical Technology  
Budget Activity: Technology Base

<u>Last Year's Report Plan</u>	<u>Current Plan</u>	<u>Milestones</u>
--	Early FY 1987	Evaluation of new armor and shaped charge materials and concepts.
--	Early FY 1987	Test of high velocity advanced KE penetrators.
--	Early FY 1988	Test of hypervelocity KE penetrators.
--	Early FY 1989	Test of lightweight applique for light armor vehicles.
--	Late FY 1990	Test of advanced shaped charge concept.

f. Explanation of Milestone Changes: This project was less than \$7 million in the FY 1986 Descriptive Summary; therefore, no milestones were addressed for the Advanced Armor Technology and the Armor Anti-Armor programs.

The Advanced Warhead Technology program was addressed under Project TT-05 in the FY 1986 Descriptive Summary and only minor changes occurred due to redefinition Adaptive Warhead development and implementation.

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Project: TT-05  
Program Element: #62702E  
USDR&E Mission Area: 530

Title: Target Acquisition and Weapons Technology  
Title: Tactical Technology  
Budget Activity: 1. Technology Base

H. PROJECTS OVER \$7 MILLION IN FY 1987:

1. Project Description: The Target Acquisition and Weapons Technology project (TT-05) is designed to help offset expected enemy numerical advantages in deployed weapons and systems through increasing the lethality and effectiveness of U.S. fielded systems. The Surveillance Radar Technology program is jointly developing with the Army a self-contained miniaturized airborne radar for short-range battlefield surveillance and targeting from a Remotely Piloted Vehicle. This program is also developing reduced-tolerance imaging techniques to permit high-resolution radar imaging without the stringent (and expensive) aircraft motion compensation normally required. Taken together, these technologies will provide for lower-cost airborne battlefield surveillance with greatly enhanced capability to detect and classify targets. Sensor and algorithm technologies for fire-and-forget munitions and other highly specialized applications are being developed in three related developments: the Autonomous Infrared (IR) Sensor Technology, the Uncooled IR Sensor Arrays, and the Millimeter Wave Autonomous Sensor programs. The Autonomous IR Sensor Technology program is structured to provide a technology base for future IR seekers and sensors associated with tactical operations such as missiles, projectiles and attack helicopter sensors. A government standard image database and image evaluation standards will be developed with which to gauge the performance of advanced algorithms and perform comparison of sensor techniques. The program is jointly managed and funded by DARPA and the Army, with active participation from the Air Force and Navy. The Uncooled IR Sensor Arrays program is developing two-dimensional imaging arrays, pyroelectric and other room temperature sensor techniques that sense IR energy. A primary application for uncooled IR imaging is in potentially low cost high production volume sensors such as missile seekers and projectiles. The MMW Autonomous Sensor program is forging the technological base for a new generation of precision-guided adverse weather weapon seekers, forward-area surveillance radars, and fire control radars. Advanced weapons, weapons lethality, propulsion and warhead technologies are being explored in the Advanced Ramjet Munition Technology (ARMT) program. The ARMT program features development of advanced solid fuel ramjet propulsion, special munition concepts and fundamental ramjet combustion phenomenology analysis. The Air Defense Technology program consists of technology

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Title: Tactical Technology

Budget Activity: 1. Technology Base

developments for advanced air defense concepts. The Infrared (IR) Binary Optics program is using new developments in holographic grating theory coupled with standard integrated circuit fabrication technology to produce flat, lightweight holographic optics for IR systems. The program goal is demonstrating the feasibility and practicability of a low cost IR telescope. This combination of techniques promises to reduce the cost of IR optics and infrared system weight. The Small Unit Technology program is exploring advanced technologies and methodologies that address functional areas, such as training, intelligence, command and control, and planning requirements of small units in all the Services. The effectiveness of small units throughout the spectrum of conflict is increasingly recognized; the objective of this program is to increase significantly the probability of small unit mission success through the application of advanced methodologies and technology to the referenced functional areas.

Until recently constraints of cost, speed, capacity and the need for conversion from analog to digital formats have hampered full exploitation of known signal processing techniques for radar, spread spectrum and LPI communications. The recent breakthrough in the Acoustic Charge Transport (ACT) process, a hybrid analog/digital device technology, makes possible small, low cost, low power microelectronic components for advanced large dynamic range, large processing gain, extremely wide bandwidth, radiation hard, radar and communication signal processing systems. Signal processors using ACT devices will replace current digital array processors with single-chip analog devices of greater capability.

2. Program Accomplishments and Future Programs:

a. FY 1985 Accomplishments:

In the Critical Node Targeting program, the design definition study for an airborne multi-sensor testbed was completed and results were transitioned to the Services.

The Advanced Warhead Technology program was transferred in FY 1986 to Project TT-04 of this Descriptive Summary.

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In the Surveillance Radar program, hardware and software development of the miniaturized Remotely Piloted Vehicle radar was begun. Analysis of reduced-tolerance imaging techniques continued and produced promising signal processing techniques.

In the Autonomous Infrared (IR) Sensor Program, algorithm development contracts were awarded to major IR investigators in industry. Standard IR imagery has been issued for evaluating algorithm performance as a function of standard image parameters, such as resolution. A synthetic IR data base is in development to augment real data. Simultaneous, multi-dimensional IR data has been collected on a variety of domestic and foreign targets. The data includes laser doppler, range, and reflectance plus passive IR images, all registered on a pixel-by-pixel basis.

In the Uncooled IR Sensor Arrays program, IR imagery has been demonstrated by four contractors, using five sensing techniques and in array sizes from 64 x 64 to 100 x 100 pixels. Sensitivity suitable for munitions seekers has been demonstrated.

In the Millimeter Wave (MMW) Autonomous Sensor program, research on MMW tactical target detection/classification techniques continued. Alternative discrimination algorithms were examined and optimized and several new algorithms discovered. Design and fabrication of an airborne radar signature testbed was initiated. Contracts for development of new target detection/classification algorithms were awarded.

In the Advanced Ramjet Munitions Technology program, ramjet-powered, rod penetrator munition (RAMROD) component testing was accomplished under high-g loadings. RAMROD projectile testing of auto-ignition, ramjet boost-sustain function, aeroballistic stability, and structural integrity was conducted. Three advanced boron fuels and a state-of-the-art hydrocarbon fuel were tested under common conditions to evaluate their potential for later flight applications.

Small Unit Technology program: Accomplishments include completion and evaluation of a concept demonstrator of a swimmer delivery vehicle (SDV) part-task trainer, implementation and evaluation of a small unit planning aid concept demonstrator, and initiation of a 62% scale prototype of an all composite Advanced Technology Tactical Transport. The SDV is a vehicle used by Naval Special Operations personnel and DARPA developed a computerized training system to enable training the operators on a much more cost

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effective fashion. Unlike a full-scale environmental simulator, a part-task trainer is a low cost, effective way to train critical system skills. The Swimmer Delivery Vehicle trainer is oriented toward pilot and navigator skills and mission rehearsal.

A concept was developed and analytically verified in the Air Defense Technology program that began in late FY 1985. A study to identify promising defensive concepts was also initiated.

Experimental ACT monolithic devices were fabricated and tests conducted to validate fabrication processes and device parameters estimated to be achievable from theoretical models. A capability to design, model, optimize, fabricate and test prototype ACT devices was evolved. Development of a basic interface module was initiated by implementing high speed processing of either analog or digital signals. This device will be combined with the ACT tap-delay line to form an analog/digital interface component. Development of four other ACT devices needed to form an analog/digital array processing component was initiated.

b. FY 1986 Program:

In the Surveillance Radar program, fabrication of miniaturized Remotely Piloted Vehicle Surveillance Radar components is being completed and integrated on a stand-off aircraft. Fabrication of the fully miniaturized signal processor has begun. Analysis of reduced tolerance imaging techniques is being completed and a follow-on demonstration program defined.

In the Autonomous Infrared (IR) Sensor program, both single and multi-dimensional sensor data are being provided and its performance is being evaluated by algorithm development teams. Evaluation of algorithms is being conducted using standardized evaluation principles. A standard sensor database is being provided for algorithm evaluation. A synthetic imagery database is being completed and compared with real imagery/. Algorithms are being evaluated using synthetic imagery and the results compared with

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similar evaluations using real imagery. A national Data Resource Center is being established to maintain the standards and to evaluate results of this program. A second generation thermal imager is being used to collect field imagery on foreign targets.

In the Uncooled IR Sensor Arrays program, three candidate design configurations of imaging arrays are being evaluated in the laboratory. The goal is to provide sensitivity in element imaging arrays of small pixels. The current study of arrays with small pixels is being jointly funded with the Army and Navy. The aim of this is to produce an anti-ship, lock-on-after-launch seeker. This development will lead to flight tests. A program with the Army will commence to develop very large arrays for TV compatible applications.

In the Millimeter Wave Autonomous Sensor program, an extensive research program is continuing to develop and optimize battlefield target detection/classification algorithms. Fabrication of an airborne radar testbed continues and is largely completed; collection of a comprehensive high resolution target/background signature database is planned. Contractors are using existing databases for algorithm development.

Advanced Ramjet Munition Technology program efforts include preliminary testing of ramjet-powered, rod penetrator munition (RAMROD) projectiles and structural integrity at high-g loadings using the M-68 105mm gun. Demonstrations of RAMROD are scheduled for early FY 1987 along with transfer of the technology to the Army. The Spin Combustion Phenomenology study is a basic research effort to perform free-jet testing of solid fuel ramjet engines at very high spin rates. Integration of these numerous experimental and modelling efforts is scheduled for completion in late FY 1986 or early FY 1987, after which the technology is to transition to the Navy or Army. Competitive award for the joint DARPA/NASA air turbo-ramjet demonstrator engine are beginning. Follow-on efforts in Light-Gas Gun technology are being evaluated.

In the Small Unit Technology program, development of the Swimmer Delivery Vehicle part-task trainer prototype is continuing, development of a concept demonstrator version of a small unit simulator is being initiated, and a small/special weapons and close quarters combat trainer concept demonstrator is being constructed. The Advanced Technology Transport proof of concept demonstrator development is being continued.

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In the Air Defense Technology program, wind tunnel testing of critical technology is being conducted at NASA Langley facilities. Other technology efforts identified in the Defensive Concepts technology study are being initiated.

The Infrared (IR) Binary Optics program is a new program in FY 1986 to develop a new class of low cost, high performance IR optical elements and laser sources. Two primary applications of major interest are: a binary optics wideband telescope for passive thermal imagers and a tactical multi-dimensional IR sensor suite using all binary optics. Binary optics employ Very Large Scale Integrated (VLSI) lithographic and dry etch techniques to produce flat, lightweight generalized optical elements that can combine a variety of conventional as well as exotic optical functions. The technology will allow mass production of high quality infrared optics using conventional integrated circuit technology. Additional spinoff in the production of coherent laser energy from solid state diode arrays is being investigated. Contracts are being awarded for IR telescope design, modular laser power, an IR scanner and components for the fabrication.

Fabrication and test of a proof-of-principle Acoustic Charge Transport (ACT) analog/digital interface (ADI) and control circuitry are being completed. Hybrid feasibility models of an analog memory and vector processing devices are being completed and tested. Application studies to apply these devices in practical military systems are being initiated.

C. FY 1987 Planned Program and Basis for FY 1987 Request:

Integration of the Remotely Piloted Vehicle (RPV) Surveillance Radar will be completed and captive flight test on a manned aircraft conducted. The system will then be transferred to a flight-worthy RPV airframe for a free-flight demonstration. Implementation and test of reduced tolerance imaging techniques will be initiated if study results warrant.

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Title: Target Acquisition and Weapons Technology  
Title: Tactical Technology  
Budget Activity: 1. Technology Base

Efforts in the Autonomous IR Sensor Technology program will continue to definitize emerging algorithm evaluation standards and define criteria for synthetic data with which to test algorithms. Multi-sensor data combining will be used in the development of high performance algorithms. A real-time processor will be developed to demonstrate results of the research to date and serve as a pilot for validation of experiments to date.

In the Uncooled Infrared (IR) Sensor program, development of very high density arrays will continue in FY 1987, leading to a TV compatible imager. Fabrication of the anti-ship seeker will proceed, leading to flight tests.

In the Millimeter Wave (MMW) Autonomous Sensor program, fabrication and checkout of the MMW target/clutter signature collection testbed will be completed and an extensive database will be established of the radar signature data gathered. Contractors and laboratories who have heretofore been using interim data will begin working more intensively with the new data. Concepts and designs for a new generation of MMW smart seekers and fire control radars will be developed.

Under the Advanced Ramjet Munition Technology program, the joint DARPA/NASA air turbo-ramjet engine technology testbed will be evaluated over the full dynamic range for which the engine is to be designed in the NASA Langley wind tunnel. Light-Gas Gun technology efforts successfully demonstrated will be evaluated in field demonstrations.

The Small Unit Technology program: The Swimmer Delivery Vehicle will be developed, evaluated and transitioned to the Navy. The small unit simulator will be demonstrated in a stand-alone mode. The first phase special weapons and close quarters combat trainer will be evaluated. Small unit testing of the Global Positioning System receiver chip set will be conducted and the Advanced Technology Tactical Transport will be completed and flight tested.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: TT-05  
Program Element: #62702E  
USDR&E Mission Area: 530

Title: Target Acquisition and Weapons Technology  
Title: Tactical Technology  
Budget Activity: 1. Technology Base

After completion of the ACT ADI analog memory and vector processing feasibility demonstration, integrated monolithic vector processors will be designed, fabricated and tested.

The Infrared (IR) Binary Optics program will demonstrate in a laboratory configuration that integrates major optical functions using binary optics. Designs for a Long Wave Infrared wideband telescope will be evaluated.

d. (U) Program to Completion:

Flight test of the Remotely Piloted Vehicle (RPV) Moving Target Indicator Radar developed under the Surveillance Radar program will be completed in early FY 1988. A new set of modes, including medium-resolution radar imaging and the incorporation of target classification algorithms developed under the Millimeter Wave (MMW) Autonomous Sensor program, will be incorporated. The radar will then undergo further flight-tests in late FY 1988 and the program transferred to the Army.

In the Autonomous IR Sensor program, a joint evaluation of the real-time processor for automatic target recognition in air-to-ground weapons will be completed in FY 1989. The processor will be a "sized" version of a selected target recognizer architecture using selected algorithm suites compatible with the volume and throughput of the processor. The chosen application will be a lock-on-after-launch terminally guided submunition. The processor is estimated to require 150 million operations per second, weigh 3 pounds, and have a volume of 60 cubic inches. Management of the Imagery Data Resource Center will transition to a tri-Service group.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: TT-05  
Program Element: #62702E  
USDR&E Mission Area: 530

Title: Target Acquisition and Weapons Technology  
Title: Tactical Technology  
Budget Activity: 1. Technology Base

In the Uncooled IR Sensor program, the anti-ship seeker will be transitioned to the Navy in late FY 1988 with evaluation of the uncooled seeker in actual flight tests. The very high density array program will transition to the Army with delivery of an imager.

Development of target detection/classification techniques by the Millimeter Wave (MMW) Autonomous Sensor program will be completed in FY 1988. Concept designs for new seekers and fire control radars will be evaluated and development initiated in FY 1989. Results for this task will be continuously transferred to the Services via a tri-Service technical liaison activity.

The Advanced Ramjet Munition Technology program will be completed with a series of demonstrations. Conceptual design efforts for an Integral Rocket-Ramjet demonstrator will be evaluated for possible development and demonstrated.

The Small Unit Technology program to completion will focus on transition of projects to the Services upon completion of their exploratory research components during late FY 1988. For example, the Advanced Technology Transport flight will have been completed as part of the transfer requirements in late FY 1988. The Small and Special Weapons Trainer and Explosives Ordnance Disposal Aid will be transitioned by FY 1938 and testing of the linkage of the Joint Special Operations Simulation with Warrior Preparation Center models will be conducted.

The Air Defense Technology program flight test technology will be completed and the effort transitioned to a free flight demonstration.

Under the Infrared (IR) Binary Optics program, the Long Wave Infrared wideband telescope will be installed on CHAPARRAL Night Sight; its performance will be compared with conventional germanium optics. A compact laser radar will be demonstrated using all binary optics; the system will be flown as part of a tactical weapons delivery program.

# FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: TT-05  
 Program Element: #62702E  
 USDR&E Mission Area: 530

Title: Target Acquisition and Weapons Technology  
 Title: Tactical Technology  
 Budget Activity: 1. Technology Base

Monolithic integration of optimized ACT devices with control and support circuitry to form a practical Analog/Digital Array Processor (ADAP) component will be completed during FY 1990 and transferred to the Services for use in appropriate radar and communication signal processing subsystems. Joint DARPA/Service programs to use ACT devices in military communication, radar, and signal receiver systems will be carried out.

## e. Milestones:

Last Year's Reported Plan	Current Plan	<u>Milestones</u>
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### Surveillance Radar Program:

--	Early FY 1987	Captive flight test, Remotely Piloted Vehicle (RPV) radar.
--	Early FY 1988	Free flight test, Remotely Powered Vehicle (RPV) radar.

### Autonomous Infrared Sensor Program:

--	Late FY 1986	First algorithm evaluation results obtained. Multi-sensor algorithm evaluated.
--	Late FY 1987	Real-time processor development initiated.
--	Late FY 1988	Data Resource Center established and transitioned to the Services.
--	Late FY 1989	Real-time target recognizer delivered and demonstrated.

# FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: TT-05  
 Program Element: #62702E  
 USDR&E Mission Area: 530

Title: Target Acquisition and Weapons Technology  
 Title: Tactical Technology  
 Budget Activity: 1. Technology Base

<u>Last Year's Reported Plan</u>	<u>Current Plan</u>	<u>Milestone</u>
<u>Uncooled Infrared Sensor Arrays Program:</u>		
--	Mid FY 1986	Initiate seeker program; begin development of full size arrays.
--	Mid FY 1987	Image full arrays, high sensitivity; fabrication of the seekers.
Late FY 1987	Late FY 1988	Program transition to Service development program.
<u>Millimeter Wave Autonomous Sensor Program:</u>		
Late FY 1987	Late FY 1988	Data collection will be completed.
Late FY 1987	Early FY 1989	Research phase will be completed.
Mid FY 1988	Late FY 1988	Seeker designs will be delivered.
Late FY 1988	Early FY 1989	Seeker designs evaluated and transitioned to the Services.

# FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: TT-05  
 Program Element: #62702E  
 USDR&E Mission Area: 530

Title: Target Acquisition and Weapons Technology  
 Title: Tactical Technology  
 Budget Activity: 1. Technology Base

<u>Last Year's Reported Plan</u>	<u>Current Plan</u>	<u>Milestones</u>
<u>Advanced Ramjet Munitions Technology Program:</u>		
Mid FY 1986	Mid FY 1986	M-68 105mm high-g firing of the ramjet-powered, rod penetrator munition (RAMROD).
Mid FY 1986	Mid FY 1986	Air turbo-ramjet technology demonstrator begins development.
Early FY 1987	Early FY 1987	RAMROD demonstration firing and transition to the Army.
Late FY 1987	Late FY 1987	Air turbo-ramjet demonstrator wind tunnel testing begins.
Mid FY 1988	Mid FY 1988	Air turbo-ramjet wind tunnel testing will be completed.
--	Early FY 1988	Light-Gas Gun demonstrations.
--	Mid FY 1989	Integral Rocket-Ramjet demonstrations.
<u>Small Unit Technology Program:</u>		
--	Mid FY 1987	Transfer of Swimmer Delivery Vehicle Part Task Trainer to the Navy.
--	Late FY 1987	Advanced Technology Tactical Transport (AT <sup>3</sup> ) flight tests.
--	Late FY 1988	Transfer of Small Unit Planning Aid to Special Operations Forces and AT <sup>3</sup> to the Services.

# FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: TT-05  
 Program Element: #62702E  
 USDR&E Mission Area: 530

Title: Target Acquisition and Weapons Technology  
 Title: Tactical Technology  
 Budget Activity: 1. Technology Base

Last Year's  
Reported Plan

Current  
Plan

## Air Defense Technology Program:

--	Mid FY 1986	Wind tunnel test.
--	Late FY 1987	Captive flight test begins.
--	Late FY 1988	Demonstration begins.

## Infrared Binary Optics Program:

--	Early FY 1986	Start contracts for Carbon Dioxide CO <sup>2</sup> laser radar components and wideband Long Wave Infrared (LWIR) telescope.
--	Mid FY 1987	Evaluate designs for telescope.
--	Late FY 1987	Demonstrate laboratory laser radar.
--	Late FY 1988	Demonstrate Long Wave Infrared telescope, fly compact laser radar.

# FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: Tr-05  
Program Element: #62301E  
USDR&E Mission Area: 530

Title: Special Application Technology  
Title: Strategic Technology  
Budget Activity: 1. Technology Base

<u>Last Year's Reported Plan</u>	<u>Current Plan</u>	<u>Milestones</u>
<u>Acoustic Charge Transport Device Program:</u>		
Late FY 1986	Late FY 1986	Complete fabrication, test and evaluate ACT feasibility model devices.
Late FY 1986	Late FY 1986	Initiate development of optimized ACT devices and ADAP feasibility model device.
Early FY 1988	Early FY 1989	Complete development of monolithic Acoustic Charge Transport (ACT) devices and evaluate Analog Digital Array Processors (ADAP) feasibility model device.
Early FY 1990	Early FY 1990	Complete development of optimized monolithic ADAP for incorporation as component in selected systems applications.

## f. Explanation of Milestone Changes:

The changes indicated in the Millimeter Wave (MMW) Autonomous Sensor program reflect a 4-month delay in contract award for the testbed sensor and a decision to stretch the data collection/research phase by one year and overlap it with the design of advanced seekers and radars.

The changes in the Advanced Ramjet Munitions Technology program reflect the initiation of the testing of further Light-Gas Gun technologies and of an Integral Rocket-Ramjet demonstrator.

The Uncooled Infrared (IR) Sensor program has expanded based on the promising results obtained in the FY 1984-1985 effort. While certain uncooled array technology has transferred much earlier, this more ambitious program will take longer.

FY 1987 RD&TE DESCRIPTIVE SUMMARY

Project: #TT-05  
Program Element: #62301E  
USDR&E Mission Area: 530

Title: Special Application Technology  
Title: Strategic Technology  
Budget Activity: 1. Technology Base

The ACT program has been moved to this project from project ST-07. The change shown above in the milestone relating to monolithic ACT development corrects a typographical error in the FY 1986 Descriptive Summary which erroneously indicated that accomplishment was expected in FY 1988 rather than FY 1989.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: #TT-06

Program Element: 62702E

USDRE&E Mission Area: 530

Title: Tactical Directed Energy Technology

Title: Tactical Technology

Budget Activity: 1. Technology Base

H. PROJECTS OVER \$7 MILLION IN FY 1987:

1. Project Description: The objective of the Tactical Directed Energy Technology Project is to develop moderate power, efficient, high brightness lasers and high power microwave source and antenna technology for a broad spectrum of military applications.

2. Program Accomplishments and Future Programs:

a. FY 1985 Accomplishments: A head start on this new project was initiated in FY 1985 by using some of the residual funds in ST-03, which is being terminated. This permitted the timely exploitation of the recent breakthroughs in linear induction accelerator technology at Lawrence Livermore National Laboratory (LLNL). An order of magnitude improvement in millimeter wave power generation was accomplished by converting the kinetic energy of the relativistic beam electrons to microwave energy. This milestone was accomplished one year earlier than projected. Continued development of efficient high power sources at millimeter wavelengths will provide new options for advanced surveillance systems. Extensions of this kind of technology to the optical wavelengths is being pursued by the Strategic Defense Initiative Organization.

The 1985 Defense Science Board Summer Study on Tactical Directed Energy Weapons (DEW) affirmed the importance of the new Tactical Directed Energy project started by DARPA in FY 1985, described below, especially since the DEW personnel and resources of the three Services have become absorbed in meeting the requirements of the Strategic Defense Initiative Organization.

b. FY 1986 Program: In FY 1986, DARPA will continue to develop the new Tactical Directed Energy project which includes the development of advanced high brightness solid state laser and microwave source/antenna technology for tactical applications. The objective of the solid state laser portion of this project is to develop the technology for efficient, compact, solid state lasers. This subtask is jointly funded with ST-09, which is providing the major funding in FY 1985 and FY 1986. The work will focus on the development of compact sources, new efficient solid state laser materials and non-linear optical materials for producing efficient wavelength conversion and for improving laser beam quality. New methods will include compact and electrically efficient diode array whose output matches an

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: TT-06  
Program Element: 62702E  
USDRE&E Mission Area: 530

Title: Tactical Directed Energy Technology  
Title: Tactical Technology  
Budget Activity: 1. Technology Base

absorption band of the laser crystals and radiation sources which takes advantage of the extremely high specific energy storage of chemical systems to produce blackbody radiation in the 4,000°K to 25,000°K range. New efficient laser materials to be developed on this project include a new class of garnet hosts which when co-doped promise to increase the efficiency of neodymium lasers and a new class of dye-impregnated plastic rods. Nonlinear optical materials such as Potassium Deuterium Phosphate, Potassium Titanium Phosphate, Thallium Arsenic Selenide and Silver Gallium Selenide will be developed and evaluated for the efficient harmonic conversion of Neodymium 1.06  $\mu$ m laser and carbon dioxide 10.6  $\mu$ m laser outputs to shorter wavelengths. The performance limits of nonlinear optical processes such as Stimulated Brillouin Scattering which have the potential to insure near perfect beam quality from both visible and near infrared lasers will also be determined.

The objective of the second portion of the project is to develop compact, efficient, high power microwave source and antenna technology. The high power, high efficiency milestone was demonstrated. Methods to make the source more compact will be studied. Methods to efficiently couple the high power microwave source to the antenna will be studied.

c. The FY 1987 Planned Program and Basis for FY 1987 Request: In FY 1987, a number of brassboards will be started based on the new Tactical Directed Energy technology program which will demonstrate the weapon potentials and capabilities for Service user's test and evaluation in their laboratories and/or test ranges. These brassboards will be joint DARPA/Service programs.

d. Program to Completion: This is a continuing effort project. The brassboard efforts will be completed and evaluated, and decisions made for future brassboard and demonstration efforts as well as for engineering development by the Services.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: #TT-06  
 Program Element: 62702E  
 USDRE&E Mission Area: 530

Title: Tactical Directed Energy Technology  
 Title: Tactical Technology  
 Budget Activity: 1. Technology Base

e. Milestones:

<u>Last Year's Reported Plan</u>	<u>Current Plan</u>	<u>Milestone</u>
Late FY 1986	Late FY 1985	Generation of microwave pulses at millimeter wavelength.
Late FY 1986	Late FY 1986	Development of a 100 watt diffraction limited solid state laser testbed at near IR wavelengths.
	Late FY 1988	Development of a 1000w solid state laser testbed with greater than 2 % efficiency.

f. Explanation of Milestone Changes: Earlier accomplishment of milestone due to SDIO interest in verifying Free Electron Laser Physics and Energy Extraction at Microwave frequencies.

# FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #62707E  
USDR&E Mission Area: 530

Title: Particle Beam Technology  
Budget Activity: 1. Technology Base

## A. RESOURCES: (\$ in thousands)

Project Number	Title	FY 1985 Actual	FY 1986 Estimate	FY 1987 Estimate	FY 1988 Estimate	Additional to Completion	Total Estimated Costs
	TOTAL FOR PROGRAM ELEMENT	\$16,400	\$20,000	\$15,500	N/A	Continuing	\$213,678

B. BRIEF DESCRIPTION OF ELEMENT AND MISSION NEED: This program supports basic research and technology development to determine the scientific feasibility of particle beam weapon concepts. If feasible these new weapons have the advantages of near speed-of-light delivery, rapid retargeting, and deep target penetration with a variety of kill mechanisms. The major objective of this effort is to demonstrate stable, predictable propagation of a relativistic electron beam within the atmosphere for potential point defense applications. To this end, DARPA developed and constructed the Advanced Test Accelerator (ATA) at the Lawrence Livermore National Laboratory as the program's major experimental installation. Through FY 1984, this program also supported research on the production of high brightness neutral particle beams for potential space applications. In FY 1985, the neutral particle beam program and certain elements of the charged particle beam program directed toward research of space based electron beam weapon concepts were transferred to the new Strategic Defense Initiative Organization.

C. COMPARISON WITH FY 1986 DESCRIPTIVE SUMMARY: The actual amount of funding available in FY 1985 was \$1 million less than the \$17.4 million estimated in the FY 1986 Summary. Consequently FY85 milestones have been reordered in favor of milestones for FY 1986-87. Further delays are a result of the Strategic Defense Initiative Paladin (Free Electron Laser) Experiment which precludes significant use of the Advanced Test Accelerator after the first quarter of FY 1986.

D. OTHER APPROPRIATION FUNDS: None.

E. RELATED ACTIVITIES: In FY 1980 the Under Secretary of Defense for Research and Engineering approved the Particle Beam Technology Program plan which, beginning in FY 1981, consolidated the DoD particle beam efforts under the overall technical direction of DARPA. Under this plan, DARPA assumed responsibility

# FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #62707E  
USDR&E Mission Area: 530

Title: Particle Beam Technology  
Budget Activity: 1. Technology Base

for both charged and neutral particle beam feasibility experiments. The Military Departments were responsible for advancing those technologies which are essential in order to rapidly develop particle beam weapons once they are proven feasible. In FY 1983, the transition to Army support began for the neutral particle beam program. In FY 1983-84, the neutral particle beam feasibility experiment was jointly supported by the Army and DARPA. For FY 1985 and the outyears, the Joint Army/DARPA neutral particle beam program will be continued as a part of the President's initiative on Strategic Defense, with funds requested under Program Element 63221C.

F. WORK PERFORMED BY: This effort is performed by in-house activities (5%), by federally funded research facilities (85%) and by industrial contractors (10%). In-house participants include: the Naval Surface Weapons Center, Silver Spring, Maryland; and the Naval Research Laboratory, Washington, D.C. Federally funded research facilities include the Lawrence Livermore National Laboratory, Livermore, California; the Los Alamos National Laboratory, Los Alamos, New Mexico; and Sandia National Laboratories, Albuquerque, New Mexico. Industrial contractors include Science Applications, Inc., Palo Alto, California; SRI International, Menlo Park, California; AVCO Everett Research Laboratory, Everett, Massachusetts; Mission Research Corporation, Santa Barbara, California; B. K. Dynamics, Inc., Rockville, Maryland; C. S. Draper Laboratories, Cambridge, Massachusetts; McDonnell Douglas Research Labs, St. Louis, Missouri; and Pulse Sciences, Inc., Oakland, California.

G. PROJECTS LESS THAN \$7 MILLION IN FY 1987: Not Applicable.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #62707E  
USDR&E Mission Area: 53U

Title: Particle Beam Technology  
Budget Activity: 1. Technology Base

H. PROJECTS OVER \$7 MILLION IN FY 1987:

1. Project Description: Charged particle beam concepts are being considered for applications in a variety of advanced weapon systems. The reason for interest in these concepts is the expectation that particle beams can deposit large amounts of energy deep within a target to deliver near instantaneous, diagnosable, hard kill at close to the speed of light.

The key issue for development of charged particle beam concepts is the capability to propagate electron beams in the atmosphere. Theoretical models for electron beam propagation have been developed and have been verified by low-energy experiments at sub-atmospheric densities. However, until now, no electron accelerators of sufficient energy and current has existed in the United States which would permit critical propagation experiments to be performed at full atmospheric densities. Such experiments are essential. Therefore, a major objective of the Particle Beam Technology Program has been to develop the required high-energy accelerator and to demonstrate the feasibility of predictably propagating powerful electron beams to distances of military interest. As a result the Advanced Test Accelerator (ATA), was developed by DARPA at Lawrence Livermore National Laboratory (LLNL) in FY 1979 to provide such an electron beam and was successfully completed in the second quarter of FY 1984. RADLAC-II, an accelerator developed jointly by Sandia National Laboratory and the Air Force Weapons Laboratory, is also playing an essential role in the DARPA program. Built using technology different than ATA, it is capable of less energy but greater current and greatly extends the parametric limits of beam propagation which can be explored.

2. Program Accomplishments and Future Programs:

a. FY 1985 Accomplishments: During FY 1985, the Advanced Test Accelerator (ATA) was used for the first time in direct experiments of propagation in reduced density air. These optimistic results are being verified in great detail prior to testing in the full atmosphere.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #62707E  
USDR&E Mission Area: 530

Title: Particle Beam Technology  
Budget Activity: 1. Technology Base

Propagation results from other machines during this year have been equally impressive. In August 1985, the first open-air propagation experiments involving a high current, high energy beam were conducted at Sandia National Laboratory using the RADLAC-II accelerator. As with the ATA, results were considerably more favorable than theoretical estimates and will be the object of further efforts in FY 1986. Other Sandia experiments suggest that the laser guiding technique first demonstrated in FY 1984 on ATA is also an exciting technology for the design of very compact recirculating accelerators.

Theoretical efforts at the Naval Research Laboratory have identified a new mode of propagation which incorporates advantageous features. This new scheme may extend beam propagation. It depends on stable beam propagation at very high beam currents (several hundred kiloamperes).

b. FY 1986 Program: The FY 1986 program will complete the single pulse experimental program to resolve the issue of lead pulse stability. Experiments will be conducted on both the ATA (medium current) and RADLAC II (high current). During the last quarter of FY 1986 the ATA pulse will be brought into the open air at full power for a final lead pulse demonstration and effects testing. Additional experiments will be conducted on several other smaller machines in support of these main activities. Exploratory efforts will continue in high current mode theory and recirculating linear acceleratory development.

c. FY 1987 Planned Program and Basis for FY 1987 Request: Building on the anticipated positive lead pulse results of ATA and RADLAC the FY 1987 program will concentrate on the other major milestone of the experimental program. Examination of these issues in FY 1987 requires procurement of hardware components in FY 1986 to enhance the multi-pulse capability of both ATA and RADLAC. To support these concepts development will continue on new technologies which will enable the design of very compact light weight accelerators capable of large accelerating gradients and repetitive operation. In addition, material interaction experiments will be conducted which will test the hypothesis that Intense Electron Beam can be used in point defense.

# FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #62707E  
USDR&E Mission Area: 530

Title: Particle Beam Technology  
Budget Activity: 1. Technology Base

d. Program to Completion: The milestone schedule of paragraph (e) has been modified thus completing the present DARPA program. With a positive resolution of both of these issues and in accordance with the recommendations of the Defense Science Board of August 1985, a joint DARPA/Services program is being planned for initiation in FY 1988. The major thrust of the new program will be the investigation of techniques to extend the range of beam propagation. Military utility will further require advanced accelerator technologies with improved techniques for pointing and tracking. Following the successful demonstration of all of these technologies, the charged particle beam program will be transitioned to the Navy for further development.

## e. Milestones:

<u>Last Year's Reported Plan</u>	<u>Current Plan</u>	<u>Milestone</u>
Early FY 1985	Mid FY 1986	Install atmospheric beam line
Mid FY 1985	Early FY 1986	Initiate atmospheric propagation experiments on ATA.
Late FY 1985	Late FY 1986	Demonstrate stable propagation for single pulse electron beam.
--	Mid FY 1987	Demonstrate the physics of pulse tracking.

f. Explanation of Milestone Changes: Beginning early in FY 1986, the availability of the ATA machine will be greatly reduced to accommodate free electron laser experiments in support of the Strategic Defense Initiative. The altered milestones above are consistent with current schedule plans which allow five months of experimental time on ATA between January 1986 and the end of FY 1987.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #62708E  
USDR&E Mission Area: 530

Title: Integrated Command and Control Technology  
Budget Activity: 1. Technology Base

A. RESOURCES: (\$ in thousands)

Project Number	Title	FY 1985 Actual	FY 1986 Estimate	FY 1987 Estimate	FY 1988 Estimate	Additional to Completion	Total Estimated Costs
TOTAL FOR PROGRAM ELEMENT							
IC-01	Distributed Information Systems	22,633	22,590	21,788	21,316	Continuing	N/A
IC-02	Advanced Command Control and Communications Technology	23,700	26,410	34,712	43,484	Continuing	N/A

B. BRIEF DESCRIPTION OF ELEMENT AND MISSION NEED: The objective of DARPA's research in Integrated Command and Control technology is to develop advanced information processing and computer-communications technology which provides a technology base for future command and control systems, and to demonstrate and evaluate them with the Services and our Allies in selected operational environments. A heavy emphasis is placed on the development of distributed communications and processing technologies to enhance survivability.

C. COMPARISON WITH FY 1986 DESCRIPTIVE SUMMARY: FY 1985 delta due to prior year inflation adjustments and program savings identified by SECDEF during FY 1986 Congressional Budget Review.

D. OTHER APPROPRIATION FUNDS:

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #62708E  
USDR&E Mission Area: 530

Title: Integrated Command and Control Technology  
Budget Activity: 1. Technology Base

E. RELATED ACTIVITIES: The internetting effort is coordinated with the Defense Communications Agency (DCA) and the Services. The Defense Data Network is utilizing the DARPA developed Internet protocols. Efforts to achieve interoperability of command and control are being coordinated with (CECOM), the Electronic Systems Command, and the Air Force Rome Air Development Center (RADC) are all conducting research in packet-switching based on the DARPA research results. RADC is also funding and coordinating efforts in distributed processing technology. A joint effort is being conducted with the National Science Foundation (NSF) to support a key initiative for access to super computer resources. The Strategic Command Control and Communications experiment is a joint effort with the Strategic Air Command (SAC), RADC and DCA. A Survivable Adaptive Planning Experiment (SAPE) is being initiated as a joint DARPA, SAC, RADC, and Joint Strategic Target Planning Staff program to develop survivable adaptive network technology and mission planning techniques. The Ft. Bragg testbed is a joint effort with the Army, with CECOM playing the lead role with the Experimental Integrated Switched Network effort of DCA and the Services. Development of security devices for the tactical environment is being carried out jointly with the National Security Agency and CECOM. Design tools are being developed by the Ada Joint Program Office and the Software Technology for Adaptable and Reliable Systems activity.

F. WORK PERFORMED BY: Universities 55%, Industry 40%, In-house 5%. The major performers are University of Southern California/Information Sciences Institute, Marina del Rey, California; Bolt, Beranek and Newman, Cambridge, Massachusetts; SRI, Menlo Park, California; Stanford University, Stanford, California; Carnegie-Mellon University, Pittsburgh, Pennsylvania; Massachusetts Institute of Technology, Cambridge, Massachusetts; MIT Lincoln Laboratory, Lexington, Massachusetts; Hazeltine Corporation, Greenlawn, New York; University of California at Berkeley, Berkeley, California; Rockwell International, Richardson, Texas; Perceptronics, Woodland Hills, California.

G. PROJECTS LESS THAN \$7 MILLION IN FY 1987: Not applicable.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: # IC-1  
Program Element: #62708E  
USDR&E Mission Area: 53Q

Title: Distributed Information Systems  
Title: Integrated Command and Control Technology  
Budget Activity: 1. Technology Base

H. PROJECTS OVER \$7 MILLION IN FY 1987:

1. Project Description: The objectives of this project are to develop and demonstrate technology for building geographically distributed information systems which can handle classified data, meet specific real-world time constraints, and be easily expanded to meet the increasing demand for information processing in DoD command, control and communications applications. Techniques are being developed to support secure distributed processing among computers on different packet networks. Mechanisms to control and regulate the performance of the internet environment are being developed. Distributed operating systems, message systems, data bases and programming environments are being developed, along with several applications which run in a distributed environment of personal workstations. Local and long-haul methodology is being developed for real time, large scale networks of interactive simulators which permit combat teams to practice critical unit skills at a fraction of the cost of today's infrequent field exercises. Advanced prototype Ada software development environments are being developed for use in a local network of advanced workstations using distributed systems technologies. Advanced distributed systems architectures are being explored and prototypes developed to enable the effective operation of a large scale heterogeneous open system. This will provide the kind of resource sharing and interoperability required to support the insertion of strategic computing technologies (PE 62301E, Project ST-10) into the distributed systems technology base.

2. Program Accomplishments and Future Programs:

a. FY 1985 Accomplishments: The internet became an effective multi-network environment supporting advanced software system development and high-level command and control applications. Protocols were developed for multimedia conferencing; the wideband network was used to demonstrate transmission of compressed packet video. An access control system for dial-in access to the ARPANET became operational. An initial release was made of the Diamond multimedia message system for use on

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: # IC-1  
Program Element: # 62708E  
USDR&E Mission Area: 53Q

Title: Distributed Information Systems  
Title: Integrated Command and Control Technology  
Budget Activity: 1. Technology Base

local network workstations. A new version (Release 4.3) of the Berkeley UNIX operating system was distributed to a set of test sites for evaluation. The use of a distributed operating system whose nodes span a set of connected networks was successfully demonstrated. An initial implementation was completed of a new approach to building fault-tolerant software systems which permits the application designer to give a high-level specification of the required fault-tolerance for specific objects in the system. The six-node distributed sensor network was outfitted with both acoustic and video sensors; algorithms were developed for distributed self-location, for distributed fusion of information from different sensors, and for tracking targets moving in groups. The network was demonstrated to be capable of real-time tracking of low-flying aircraft. A low cost prototype simulator for the M1 Tank was completed and two prototypes were networked to test the core architecture for larger SIMNET networks (company and battalion level). This new simulator has more capability than today's simulators at 1/100th the cost. It can be operated at a fraction of the cost of operating a real combat vehicle for training.

b. FY 1986 Program: Multimedia conferencing techniques are being demonstrated for distributed real-time applications on the Internet system. New end-to-end communication services are being developed and demonstrated, including services to support multimedia conferencing. Interoperability of the Internet system with commercial systems is being explored, including electronic mail and exchange of usage information. Experimentation and evaluation of advanced algorithms for tracking multiple targets, information fusion of multiple views using video and acoustic inputs, and position self-location are being performed. The distributed sensor network program is being completed; the theoretical foundations, algorithms, and techniques will be published. The Internet Private Line Interface is being certified to permit its use as an end-to-end encryption device for sending classified data through a packet-switched internet. DES-based privacy devices are being procured for use on the ARPANET; the same type devices are being used to provide compartmentation of a secure local network in a demonstration system. The Diamond multimedia message system is being tested by military users in the Ft. Bragg testbed. New network partition-recovery mechanisms developed to support the SAC testbed (Project IC-2) are being thoroughly tested and

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USDR&E Mission Area: 530

Title: Distributed Information Systems  
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enhanced. Eight SIMNET simulators (two platoons) are being installed at a field test site at Ft. Knox to begin developing the networking technology for connecting several hundred simulators (multi-battalion combat). This site will expand to a network of 30 simulators by the end of the year. Design of an advanced prototype Ada environment using distributed system technology is starting. Advanced software engineering laboratories are being established to support Ada environment research and technology transition. Advanced distributed systems architectures are being designed in preparation for initial prototype development and evaluation.

c. FY 1987 Planned Program and Basis for FY 1987 Request: Techniques will be developed to support a very large number of nodes and priority traffic on the Internet. Interoperability of the Internet with commercial systems will continue to be explored and demonstrated. Applications of very high speed networking will be explored along with the protocols and techniques needed to support such applications. Design and implementation will begin of a new distributed operating system nucleus based on advanced object-oriented design techniques; this nucleus will provide distributed system support for other software systems such as the UNIX operating system and an Ada programming environment. Privacy devices will be installed on the ARPANET. Two SIMNET sites will be activated and long-haul networking will be tested. Evaluation of SIMNET technology for use in the Reserve Component armories will be assessed. Design of the advanced prototype Ada environment will be completed and prototype development started. Advanced distributed systems architectures will be prototyped and evaluated as a new foundation for the insertion of strategic computing technologies.

d. Program to Completion: The Internet environment will become a tightly integrated network of networks. Interoperability with other protocol systems will be explored. Techniques will be developed and demonstrated for providing the required real-time data communication to support distributed command and control applications in an Internet environment. Techniques will be developed and demonstrated to permit user-specified tradeoffs between transparency and autonomy in a distributed operating system. Mechanisms will be developed which permit integrated operation of very large distributed systems with thousands of nodes. A distributed operating system will be developed

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and demonstrated in which support of nodes spread across an internetwork is included in the fundamental design of the system. A distributed system design approach will be developed in which the distributed and fault-tolerant nature of replicated objects is a basic property of the objects themselves, allowing the designer of a distributed application to proceed as if he were creating a simpler non-distributed design. Four SIMNET test sites will be populated with battalion sized task forces of simulators (tanks and armored personnel carriers) to evaluate the SIMNET concept and establish the DoD standards for large scale interactive simulator networks. This research will be finished in FY 1989 upon completion of the final long-haul networking tests. A prototype advanced Ada environment will be developed suitable for use with a new generation of AI-based software and system tools. The new distributed operating system nucleus will be implemented in Ada using advanced software engineering and formal specification techniques. The computing environments of major research centers will transition to the new foundation of advanced distributed systems to enable the exploitation of a new machine intelligence base developed by the Strategic Computing program.

## e. Milestones:

Last Year's Reported Plan	Current Plan	Milestone
Late FY 1985	Mid FY 1986	Demonstrate multimedia message system in Ft. Bragg testbed.
Early FY 1985	Mid FY 1986	Certify manually rekeyed end-to-end encryption system for use at Ft. Bragg.
Under Consideration	Mid FY 1986	Initiate installation of privacy devices on ARPANET.

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Title: Distributed Information Systems  
 Title: Integrated Command and Control Technology  
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Project: # IC-1  
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<u>Last Year's Reported Plan</u>	<u>Current Plan</u>	<u>Milestone</u>
Mid FY 1986	Mid FY 1986	Demonstrate interoperability of the internet with commercial networks.
Mid FY 1986	Mid FY 1986	Initial testing of long haul simulator network commences.
Mid FY 1986	Mid FY 1986	Demonstrate acoustic/video tracking.
Late FY 1986	Late FY 1986	Demonstrate multimedia conferencing system.
-----	Late FY 1986	Install eight M1 simulators (two platoons) at Ft. Knox.
-----	Mid FY 1987	Complete initial design of object-based distributed operating system nucleus
-----	Mid FY 1987	Install eight M2 simulators (two platoons) at Ft. Benning.
-----	Mid FY 1987	Complete design of advanced prototype Ada programming environment.
-----	Late FY 1988	Complete initial prototype of new distributed system foundations.

f. Explanation of Milestone Changes: Multimedia message system demonstration in Ft. Bragg testbed slipped several months due to late delivery of workstation hardware from the manufacturer.

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Project: # IC-1  
Program Element: # 62708E  
USDR&E Mission Area: 53Q

Title: Distributed Information Systems  
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Certification of end-to-end security device for the Ft. Bragg and SAC testbeds delayed due to need to incorporate additional software security requirements.

Milestone date for initiation of ARPANET privacy effort has been established following a policy decision to build and install the devices.

The AI-based software and systems projects were transferred to the new generation software and systems program (PE 62301E, Project ST-11) and are no longer listed above.

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Project: # IC-2  
Program Element: # 62708E  
USDR&E Mission Area: 530

Title: Advanced Command Control Communications Technology  
Title: Integrated Command and Control Technology  
Budget Activity: 1. Technology Base

H. PROJECTS OVER \$7 MILLION IN FY 1987:

1. Project Description: The objectives of this project are to develop and demonstrate advanced command and control technology and transfer it to the Services and Agencies. Survivable, intelligent networks are being explored which can function in the presence of jamming, spoofing and the loss of communication resources, and techniques are being developed for utilizing and controlling large-scale communication networks consisting of hundreds of nodes. Low-cost packet radios are being procured to support experimentation with large scale networks. A survivable communications network architecture consisting of multiple, low-orbiting, low-cost satellites is being investigated. A methodology is being developed for rapid implementation of prototype systems using computing technology and communication networks to permit the separation of the design and fabrication processes. This methodology will reduce to a few weeks the development time for defense-critical very large scale integrated circuit (VLSI) components. The Army/DARPA Distributed Communication and Processing Experiment (ADDCOMPE), a joint testbed program, is being carried out with the Army at Ft. Bragg, NC and other key locations to develop distributed ADP applications for evaluation in a tactical operational environment, evolve innovative system concepts for the use of computers in support of future Army requirements, and develop doctrine for distributed processing in the Army concept for the 21st century. A Strategic C3 Experiment is being conducted jointly with Defense Communications Agency and the Strategic Air Command (SAC) to evaluate the use of packet radio technology, internetting, and distributed data base technology as a basis for providing survivable communications and for rapid reconstitution of strategic communications following a major attack. Secure multimedia conferencing architectures, protocols and devices are being developed and validated in the internet system. Architectures, techniques and tools for constructing very large evolutionary command and control systems are being developed and validated, using the secure multimedia conferencing application as a basis for demonstration. A Survivable Adaptive Planning Experiment (SAPE) is being initiated as a joint DARPA, SAC, Rome Air Development Center, and Joint Strategic Target Planning Staff program to develop survivable adaptive network technology, to demonstrate critical elements of

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Title: Advanced Command Control Communications Technology  
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a survivable strategic C3 environment, and to demonstrate a rapid adaptive strategic mission planning capability operating in that environment.

2. Program Accomplishments and Future Programs:

a. FY 1985 Accomplishments: Development of the initial version of software for low-cost packet radio continued. Performance enhancements were explored along with access control and protection of network resources in the face of sophisticated threats. Routing algorithms were simulated and analyzed and a selection made for implementation. A node tracker algorithm was also selected. Development of the low-cost packet radio prototypes was completed. A preliminary concept was developed for survivable, global data communications based on low-cost, low-orbiting satellites, and competitive RFPs were released to industry for preliminary designs. The very Large Scale Integrated (VLSI) fast turnaround fabrication service, called MOSIS, used commercial vendors to produce over 2000 designs submitted over computer networks by researchers representing over 100 organizations. Access was provided to several semiconductor processes including 3 micron NMOS and CMOS and 4 micron CMOS/SOS. Wafer level screens were installed to enable fabrication of complex circuits having up to 100,000 transistors. Quality assurance tests were installed to measure vendor compliance to process specifications. Work was initiated on semiconductor process synthesis using the FABLE language and flexible scheduling to enable efficient use of high volume production lines for prototype runs. The ADDCOMPE testbed was established at Ft. Bragg, NC, including packet radio networks, packet switch overlays to Army multichannel radios, local area networks, gateways to wide area networks, workstations, and host computers. The testbed includes four mobile demonstration vehicles that can be deployed to other Army testbed sites. Several major exercises, demonstrations and tests with Army forces in the US and Europe were carried out, including demonstration of interoperability between UK and US packet radio networks via gateways, a self-location capability via the Global Positioning System, and a distributed tactical information control system. Experimentation involving multiple network partitions was conducted using an airborne packet radio network, the ARPANET, and local area networks. Database partition recovery software was developed

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and tested with databases and application reports supporting the Strategic Air Command's post-strike bomber recovery mission. Initial testing was performed on a command and control planning advisor based on machine intelligence technology.

b. FY 1988 Program: The initial version of the low-cost packet radio (LPR) software is being designed, tested, and installed in a number of testbeds, to include those at Ft. Bragg and HQ SAC. Software development to support large survivable networks is being initiated, beginning with detailed design of algorithms and packet formats. A study of the security requirements for large survivable networks is also beginning. Multiple contracts are being awarded for preliminary designs and to support the multiple satellite system. The MOSIS system will continue to accept research designs and to provide NMOS and CMOS fabrication services for the U.S. research and education community. Under a joint program with NSF, a new streamlined service is being implemented to provide fabrication to U.S. university classes at costs appropriate to lab fees. A common baseline foundry automation system is being developed to enable easy transfer of the results of research programs at several universities to defense agencies and contractors. An extension to the MOSIS system is being prototyped to enable easy, rapid and inexpensive acquisition of electronic components. Several distributed command and control application demonstrations are being developed in the ADDCOMPE testbeds, including automated message generation and distribution, maneuver planning and control, fire support, and tactical communications network monitoring and reconfiguration. Multimedia conferencing prototype systems are being implemented on the basis of existing DARPA-developed multimedia mail systems. Techniques for describing and evaluating very large C3 system architectures are being explored and compared. Integration is being completed of all components of the Strategic C3 Experiment testbed, including the bomber recovery application, the internet reconstitution software and hardware, the partition-recoverable distributed database manager, the strategic planning aids, and the network security devices. A series of tests is being conducted constituting a total system demonstration of the technology developed in this program, with completion of the program

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planned by the end of the fiscal year. Initial technical planning activities are starting for the Survivable Adaptive Planning Experiment.

c. FY 1987 Planned Program and Basis for FY 1987 Request: The results of the final system demonstration for the Strategic C3 Experiment will be evaluated and documented. Low-cost Packet Radios will be installed in the Ft. Bragg and SAC testbeds. Experimentation with techniques improving survivability and security will begin. Preliminary designs for the multiple satellite system will be completed and requests for proposals to build a prototype system will be released to industry. The MOSIS system will continue to provide access to a spectrum of semiconductor processes from 3 micron geometries down to 1.2 microns. Extensions to the MOSIS system for the acquisition of mechanical components and assemblies will be investigated. Foundry automation methods will be developed for the integration of advanced semiconductor manufacturing equipment and the computing and software systems needed to model and control semiconductor processes. The ADDCOMPE distributed command and control applications will be evaluated and evolved with continuous feedback from Army users in the Ft. Bragg and other testbeds. Solutions to the tactical end-to-end security problem will be developed in cooperation with the Army and the National Security Agency. A protocol suite to support multimedia conferencing over the Internet will be specified and tested. Methods and tools for specifying and developing very large C3 systems by evolution and assimilation will be defined and tested, using the multimedia conferencing application as a basis for demonstration. An architecture and devices for ensuring privacy of multimedia conferences in very large C3 systems will be developed as a means for exploring distributed systems security architectures. Packet radio and data processing equipment remaining in place at SAC from the Strategic C3 Experiment will be augmented with additional equipment to build a testbed of internetworked processing elements for the Survivable Adaptive Planning Experiment. Utility programs and an internetworked distributed operating system will be integrated into this testbed to provide automated resource management, data distribution, and failure recovery for distributed command and control applications. Initial design will begin of automated software systems to facilitate adaptive strategic mission planning, using recent advances in machine intelligence and user interface technology. Airborne link testing will be performed of a survivable

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high bandwidth communication capability based on packet switching nodes aboard long-endurance airborne platforms.

d. Program to Completion: A network management system for large scale survivable networks will be developed and evaluated. Position location and end-to-end security capabilities will be integrated into the network. Multiple satellite system prototype components will be tested on atmospheric vehicles such as high altitude RPVs. The MOSIS system will continue to provide access to advanced semiconductor processing in support of the U.S. research community. Application of the MOSIS system will be extended to the prototyping and demand production of semiconductor components for defense agencies and contractors. The use of electronic mail in support of logistics applications will be extended to incorporate the demand manufacturing of electrical and mechanical components and assemblies. Computer integrated manufacturing methods will be applied to semiconductor manufacturing testbeds and extended to other manufacturing technologies. Distributed command and control experiments in the Ft. Bragg and other Army testbeds, involving low cost packet radios, tactical end-to-end security devices, and distributed command and control applications, will be completed, evaluated, and transferred to the Army. An evolutionary systems development method and toolset for very large C3 systems will be demonstrated and validated in cooperation with one or more of the services, using secure multimedia conferencing as a basis for demonstration. A highly survivable wide-area high bandwidth data communication system will be developed and employed in support of the Survivable Adaptive Planning Experiment. An intelligent multiband controller will be demonstrated which adaptively selects among various communications channels and media to maximize communications reliability. Command and control experiments will be conducted to exercise a rapid adaptive strategic mission planning capability whose components are replicated and distributed to provide trans- and post-attack endurance. New machine intelligence technology will be used to develop an "intelligent platform network" which uses autonomous control of airborne communications platform position to adaptively maximize network connectivity.

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## e. Milestones:

Last Year's Reported Plan	Current Plan	Milestone
Mid FY 1985	Mid FY 1986	Integrate security devices into packet radio networks at Ft. Bragg and SAC.
Mid FY 1986	Mid FY 1986	Initial Low-cost packet radio network delivered to testbeds.
-----	Mid FY 1986	Preliminary design contracts awarded for Multiple Satellite System.
-----	Mid FY 1986	Demonstrate initial set of ADDCOMPE utilities and prototype command and control applications in the Ft. Bragg testbed.
Late FY 1986	Late FY 1986	Demonstrate total system operation in Strategic C3 Experiment at Offutt Air Force Base.
Late FY 1986	Late FY 1986	MOSIS supports compatible 3 micron and 1.2 micron CMOS fabrication.
Late FY 1986	Late FY 1986	Mil Spec quality control demonstrated.
-----	Late FY 1986	Demonstrate multimedia conferencing system.

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<u>Last Year's Reported Plan</u>	<u>Current Plan</u>	<u>Milestone</u>
-----	Early FY 1987	Develop method for evolutionary development of very large C3 systems.
-----	Mid FY 1987	Preliminary designs completed for the Multiple Satellite System.
-----	Mid FY 1987	Automated acquisition of electronic parts demonstrated.
-----	Mid FY 1987	Large numbers of Low-cost Packet Radios delivered to testbeds.
Late FY 1987	Late FY 1987	Automated foundry operation demonstrated.
-----	Late FY 1987	Demonstrate command and control simulator network.
-----	Early FY 1988	Prototype intelligent multiband controller demonstrated.
Mid FY 1988	Mid FY 1988	Demonstrate large scale survivable network.
Mid FY 1988	Mid FY 1988	Demonstrate low-cost multi-satellite communication in the laboratory.
-----	Mid FY 1988	Airborne link testing of survivable comm system completed.

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Last Year's Reported Plan	Current Plan	Milestone
Late FY 1987	Late FY 1988	Remote access of mechanical manufacturing demonstrated.
-----	Late FY 1988	Internet distributed operating system demonstrated in SAPE testbed.
-----	Late FY 1988	Airborne demonstration of Multiple Satellite concept.
-----	Mid FY 1989	System demonstration of intelligent multiband communication network.
-----	Late FY 1989	Begin full system demos of survivable communications using high bandwidth packet switches on long endurance airborne platforms.
-----	Late FY 1990	Demonstrate integrated survivable adaptive planning capability.
-----	Mid FY 1992	Demonstrate intelligent airborne platform network.

f. Explanation of Milestone Changes: Integration of security devices (IPLIs) into testbeds has slipped due to decision by another agency not to complete IPLI development. DARPA has funded completion of the development to a level suitable for testbed use of the IPLIs.

Airborne demonstration of Multiple Satellite concept has been adjusted based on more extensive planning.

# FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #62712E  
USDR&E Mission Area: 530

Title: Materials and Electronics Technology  
Budget Activity: I. Technology Base

## A. RESOURCES (PROJECT LISTING): (\$ in Thousands)

Project Number	Title	FY 1985 Actual	FY 1986 Estimate	FY 1987 Estimate	FY 1988 Estimate	Additional to Completion	Total Estimated Costs
	TOTAL FOR PROGRAM ELEMENT	\$26,876	\$29,490	\$34,660	\$42,600	Continuing	N/A
MPT-1	Materials Processing Technology	\$20,205	\$22,940	\$25,200	\$28,600	Continuing	N/A
MPT-2	Electronics Processing Technology	\$ 6,671	\$ 6,550	\$ 9,460	\$14,000	Continuing	N/A

B. BRIEF DESCRIPTION OF ELEMENT AND MISSION NEED: This program element develops novel materials, processes, structures and device technologies that will give new capability to future defense weapon systems. Examples are: application of rapidly solidified superalloys and metal single crystal technology to enable higher temperature operation of gas turbine engine components; development of ceramic matrix and carbon/carbon composites for high temperature structural applications; advanced fabrication methods for structural materials; metal-matrix composites for space structures; strong ceramic fibers from polymer precursors for spacecraft and engine components; intelligent materials processing; and intelligent task automation aimed at establishing the technology base for advanced sensory controlled robotic systems. In electronics, the emphasis is on the development of second generation gallium arsenide (GaAs) based solid state circuit technology for military applications. Examples are: bipolar and enhancement/depletion mode gate arrays, computer aided design (CAD) systems, analog to digital converters and biotechnology based materials development for electromagnetic countermeasures. These efforts will provide significant performance advances for communications subsystems as well as extending the bandwidth

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of tactical Electronic Counter Measures (ECM) and Electronic Counter-Counter Measures (ECCM) subsystems.

C. COMPARISON WITH FY 1986 DESCRIPTIVE SUMMARY: Because of severe fiscal constraints which have been imposed since last year, the following decreases have occurred within the 62712E program element. The FY 1986 decrease of \$3.5M has forced the termination of two on-going programs; first, the development of high temperature bearings for cruise missile engines, and second, the high energy, high power density battery research. In FY 1987, the \$11.3M decrease will preclude the planned additional materials research initiatives including exploitation of advanced bulk crystal growth technology and computer based manufacturing process simulations. These materials initiatives would have provided the materials preparation and processing technology required to implement new systems concepts in the 1990's.

D. OTHER APPROPRIATION FUNDS: None.

E. RELATED ACTIVITIES: In MPT-1, carbon-carbon research and development programs are currently underway at the National Aeronautics and Space Administration (NASA) (for airframes) and the Air Force Materials Laboratory (AFWAL) with the goal of 1370°C turbine inlet temperature operation. Programs to develop high performance ceramic materials for gas turbine engine components are being conducted by all the Services, NASA, and the Department of Energy; plans and programs are reviewed by an Interagency Ceramics Coordinating Committee. The ceramic fibers from polymer precursors program is reviewed by an interagency steering committee established by DARPA for that purpose. Generally, the Services are sponsoring research related to unique manufacturing methods which are different than those being pursued by DARPA, and duplication of effort is prevented by direct coordination through the Office of Under Secretary of Defense for Research and Engineering (OUSDRE), the Manufacturing Technology Advisory Group (MTAG), COMAT which is a committee under the aegis of the White House Office of Science and Technology Policy, and the Interagency Materials Group which is hosted by the National Science Foundation. The intelligent task automation program is related to, complemented by and coordinated with efforts by the Air Force Wright Aeronautical Laboratories, the National Bureau of Standards, Air Force Office of Scientific Research, Office of Naval Research, and the Office of the Director of Army Research. In MPT-2, developments in electronic materials, device concepts, and processing methods are coupled to

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the services' programs through the DARPA agents, joint funding agreements, annual DoD-wide program reviews, and reviews with OUSDRE's Advisory Group on Electron Devices (AGED), to assure that no unnecessary duplication of effort occurs. First generation gallium arsenide technology development is managed by DARPA for the Strategic Defense Initiative Organization (SDIO).

F. WORK PERFORMED BY: In MPT-1, approximately 68% of the work is performed by industry, 10% universities, 14% foreign, and 8% in-house. The top industrial performers (including foreign) are: Kongsberg Vaapenfabrikk, Oslo, Norway; Dow Corning Corporation, Midland, Michigan; United Technologies Research Center, East Hartford, Connecticut; and Martin Marietta Aerospace, Denver, Colorado. The universities include: Massachusetts Institute of Technology, Cambridge, Massachusetts; University of Texas, Austin, Texas; Stanford University, Palo Alto, California. The Naval Research Laboratory, Washington, D.C., and Naval Air Development Center, Warminster, Pennsylvania perform in-house research.

In MPT-2, approximately 43% of the work is performed by industry, 55% by universities, and 2% in-house. The top performers are: TRW, Redondo Beach, California; Texas Instruments, Dallas, Texas; Stanford University, Palo Alto, California; and Cornell University, Ithaca, New York.

G. PROJECTS UNDER \$7 MILLION IN FY 1987: Not Applicable.

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Project: MPT-1  
Program Element: #62712E  
USDR&E Mission Area: 530

Title: Materials Processing Technology  
Title: Materials and Electronics Technology  
Budget Activity: 1. Technology Base

H. PROJECTS OVER \$7 MILLION IN FY 1987:

1. Project Description: The objective of this project is to develop a variety of material systems and processes for use in high performance DoD applications. The specific programs include: melt and deformation processing of vacuum arc double electrode remelt (VADER) superalloys for advanced turbine applications; the development of advanced composite materials such as metal matrix, ceramic matrix and carbon-carbon composites; the processing of ceramic fibers and whiskers; the fundamental characterization of carbon-carbon processing; intelligent task automation aimed at establishing the technology base for advanced sensory controlled robotic systems; the development of a dual entry radial turbine engine (DARPA DART Demonstrator) for testing and demonstration of high temperature structural materials under realistic gas turbine conditions; and intelligent processing of materials, a revolutionary approach to improve the way in which materials are made and to accelerate their transition from research and development into production.

DARPA has pioneered ceramic matrix and carbon-carbon composites for turbines and other advanced power plants because these materials promise engine designs with reduced weight, increased performance, reduced dependence on costly and critical alloy materials, and the lower specific fuel consumption gained by operation at high temperatures. An effort is being undertaken to develop a coating system for carbon-carbon composites which will permit their use in engines at temperatures in excess of 1930°C. The technology for obtaining oxidation resistant ceramic fibers and ceramic matrix composites is also underway. The ceramic composites being developed will offer high strength, laser resistant and fracture resistant materials for a wide range of applications including spacecraft structures and power systems, engine components, armor, infrared windows and composite gun barrel liners.

The intelligent task automation program is aimed at establishing the technology base for advanced sensory controlled robotic systems.

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Project: MPT-1  
Program Element: #62712E  
USDR&E Mission Area: 530

Title: Materials Processing Technology  
Title: Materials and Electronics Technology  
Budget Activity: 1. Technology Base

The purpose of the vacuum arc double electrode remelt (VADER) process is to scale up the remelt process to produce ingots for large turbine components, by applying the fundamental understanding of the deformation behavior of superalloys to fabrication of a full size turbine disk.

A program of fundamental experimental work has been initiated to determine the critical processes in carbon-carbon processing, to achieve higher strength and improved fabrication capability.

Research in metal matrix composites focuses on novel processing methods to attain in-situ reinforcing particulates and filaments in metallic matrices for high specific strength and modulus materials requirements. Specific applications include those where multifunctional capabilities such as high strength and electrical and thermal conductivity (e.g. rocket engines, electromagnetic launchers) are needed.

The intelligent processing of materials is a new program in which sophisticated process models and in-situ, real time sensors are being developed and combined with artificial intelligence approaches to control the way in which structural and electronic materials are processed.

2. Program Accomplishments and Future Programs:

a. FY 1985 Accomplishments: In the ceramics from polymers effort a detailed study of the causes of thermal instability in ceramic fibers led to recommendations for fiber compositions which should have stability significantly better than the current state-of-the-art Japanese fibers. Ceramic matrix composites with high strength and toughness also were demonstrated in this program. In the effort to scale-up the production of silicon carbide whiskers, process improvements in the laboratory scale reactor have produced runs with yields up to 270% of the original value.

In the effort to develop oxidation protection for carbon-carbon composites, four coating concepts were evaluated to meet the endurance requirements of integrally bladed rotors in an advanced cruise missile engine; the two best coating systems were selected for further development. Evaluation of the dual alloy radial turbine (DART) engine design was successfully completed and final fabrication was

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Title: Materials Processing Technology  
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begun. The DARPA DART Demonstrator layout was completed, aerodynamic and structural design was developed, and construction of a test cell was initiated. Deformation processing of VADER prepared superalloys by multi-step forging was successfully applied to a mid-scale turbine component disk shape with stress rupture properties several times greater than those from the state-of-the-art powder processing route for the alloy.

In the intelligent task automation program the feasibility was demonstrated of developing a robot capable of inspecting an F-15 bulkhead and of planning the inspection steps. Also, the feasibility of a vision-based robot assembling a microswitch from switch parts dumped on a tray was shown. The concept of a flexible, bellows-like manipulator was developed by comparing its dynamics and structure to an elephant's trunk. The dexterous control of a hand and fingers was extended to three fingers and combined with force sensing to permit handling of delicate objects.

Metal matrix composite research included studies on graphite/magnesium composites for space structures which require zero coefficient of thermal expansion and high specific strength and modulus in tubular members and structural joints. The technology for producing these composites was demonstrated, with continuing efforts to tailor the specific properties of the composite for specific structural application. A program to examine the strengthening mechanisms of high thermal conductivity fiber reinforced composites for propulsion systems was initiated.

A new program in electromagnetic processing of materials was initiated utilizing various electromagnetic energy sources for improved processing of structural materials having limitations in production that degrade performance. Sources of extremely high current were utilized to sinter refractory metal powders, which would degrade during conventional processing.

In the battery efforts, the successful operation of a rotating dynamic cell using a lithium anode and an acid electrolyte was demonstrated for the first time with respectable power levels of 50 Watts/sq cm.

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Program Element: #62712E

USDR&E Mission Area: 530

Title: Materials Processing Technology

Title: Materials and Electronics Technology

Budget Activity: 1. Technology Base

b. FY 1986 Program: The structural ceramics effort continues to develop and test ceramics and ceramic composites for applications in high temperature gas turbine engines, radar absorbing structures, and armor applications. Fibers with increased thermal stability are being produced and incorporated into ceramic matrix composites.

A new effort is being initiated to evaluate the state-of-the-art in ceramic composites for their applicability to small, lightweight gas turbine engines. A program begun late in FY 1985 is examining the use of ceramics as erosion resistant, lightweight liners for gun barrels, by establishing designs and preparing materials for testing. The process improvements in the whisker growth program are being incorporated into the pilot plant reactor to get the yield up to desired quantities and quality.

In the carbon-carbon composites oxidation protection program, data is being compiled for uncoated substrate materials to evaluate the effects of oxidation protection coatings on substrate properties. Also, stressed testing is being conducted on an advanced burner rig and oxidation testing is being performed on stressed coated carbon-carbon subelements.

The first DARPA/DART Demonstrator turbine engine is being fully assembled and functional testing is starting, including aerodynamic testing of the turbine stage, and testing of the DART rotor. A 50-hour endurance test, including temperature cycling, is being carried out. Current efforts in the vacuum arc double electrode remelt (VADER) process include completion of thermal and fluid flow models for the process, and incorporation of deformation mapping techniques to optimize deformation processing of full scale turbine components.

In the effort to determine the fundamentals of carbon-carbon composites processing, matrix and fiber constituent materials are being selected for characterization of the chemical and structural changes during processing. The structure-property relationships of fiber surface modifications due to new technologies (intercalation, ion implantation,...) are being identified.

The intelligent task automation program is designing two robots to demonstrate the integration of advanced robotic technology. One robot is capable of inspecting an F-15 bulkhead and planning the

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: MPT-1  
Program Element: #62712E  
USDR&E Mission Area: 530

Title: Materials Processing Technology  
Title: Materials and Electronics Technology  
Budget Activity: 1. Technology Base

inspection steps, and the other can assemble a microswitch from the switch's parts dumped on a tray. Other projects are being directed toward the development of lighter weight robotic arms, improved control schemes, greater dexterity of hands, and improved muscles.

The efforts in the intelligent processing of materials are beginning to establish the sensor and process models which are needed. An architecture for the artificial intelligence control scheme is being designed and constructed.

c. FY 1987 Planned Program and Basis for FY 1987 Request: In the ceramics from polymers effort selected ceramic fibers and ceramic matrix composites will be optimized and evaluated for applications of interest to DoD such as high temperature engines, radar absorbing materials and armor. Transition to Service Man-Tech programs will be established. The effort to evaluate ceramic composites for engines will continue. The output of this program should provide incentive for transition to the Services of the composites developed in the ceramics from polymers program. The ceramics for gun barrel liners effort will continue with the testing of ceramics in both single shot and multiple shot firings. The silicon carbide whisker program will end this fiscal year with the demonstration of the production of pilot scale quantities ( 5lbs/day) of high quality whiskers.

Evaluation of carbon-carbon composites oxidation protection systems will continue by performing an iterative analysis of the rotor design as the results of the coating materials development become available. A rotor subelement, with oxidation protection, will be designed, fabricated and tested in a hot spin rig where the component temperature reaches 1930°C in a combustion gas environment.

Demonstrations of the capability of the dual alloy radial turbine (DART) rotor will be carried out in a Demonstrator, at elevated temperatures and under cyclic conditions. A lifetime determination will

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be made. Delivery of the Demonstrators will begin to locations determined to best serve the DoD materials and engine communities.

In the investigation of the fundamentals of carbon-carbon composites processing, previous work on the characterization of fiber and matrix materials will be extended to unidirectional composites. First, models will be developed relating mechanical responses to basic fiber/matrix properties, and second, procedures will be developed for preparing carbon-carbon composites and measuring their thermophysical properties.

Processing of full-scale turbine components using the vacuum arc double electrode remelt (VADER) process will be demonstrated via a transition to an Air Force/Army manufacturing technology project on fine-grained ingot processing.

The intelligent task automation program will continue the development of two robots to demonstrate the integration of advanced robotic technology. The program will start a third such project directed toward a demanding mission to be identified. Other projects will be selected to develop the technology required for high performance and intelligent robotic components.

The intelligent processing of materials effort will begin to incorporate sensors and models into the artificial intelligence framework. The development of an expert system in a representative material process will be initiated.

In the electromagnetic processing program, optimization of pulsed power from very high power systems will occur, which will lead to future activities to consolidate refractory metals and intermetallic powders for high temperature structural applications.

Intermetallic metal matrix composite processing routes will be more firmly established for formation of in-situ and hybrid reinforcements which control strength, modulus, and creep in propulsion and other air vehicle structures exposed to high temperatures.

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d. Program to Completion: This is an on-going program which will continue to assess DoD materials needs and to develop and demonstrate novel concepts to meet them. Some specific efforts which will be completed and/or transitioned are described below.

Selected ceramic fibers and ceramic matrix composites will be optimized and evaluated for applications of interest to DoD such as radar absorbing materials or space power structural components. Interface with and transition to the Services, especially the Air Force and Navy, will be of primary consideration. If the initial testing of ceramics as gun barrel liners is successful, this program will be expanded to include the newer ceramic composites coming out of the other DARPA efforts.

The DARPA research effort to establish rapid solidification technology (RST) will be completed in FY 1987, with many major new thrusts having been established in Service programs which are based on RST, and many successful transitions to military applications, such as in turbine propulsion systems where RST superalloys and titanium components have led to much greater thrust to weight ratios and turbine inlet temperatures in current and next generation propulsion systems. The major new Air Force and Navy initiatives in higher temperature, higher strength and modulus aluminum and titanium alloys for airframe structures are derived directly from the DARPA effort in RST.

The intelligent processing of materials program will continue to address the key issues leading to the demonstration of the concept.

e. Milestones:

<u>Last Year's Reported Plan</u>	<u>Current Plan</u>	<u>Milestones</u>
Early FY 1985	Early FY 1986	Spin ceramic fibers with physical properties equal to Japanese fiber with superior oxidation resistance.

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<u>Last Year's Reported Plan</u>	<u>Current Plan</u>	<u>Milestones</u>
- -	Late FY 1987	Delivery of completed and tested DARPA/DART Demonstrators to U.S. locations.
Early FY 85	Early FY 1986	Initiate development of two robotic systems to demonstrate intelligent task automation.
Late FY 1985	Mid FY 1986	Delivery for final testing of DARPA Dual Alloy Radial Turbine (DART) Demonstrator rotors.
Mid FY 1986	Mid FY 1986	Develop superior oxidation resistant coatings for carbon-carbon composites.
Late FY 1985	Late FY 1986	Pilot plant scale production of silicon carbide whiskers.
- -	Early FY 1987	Demonstration of capability of producing graphite/magnesium zero coefficient of thermal expansion composites for space structures via a prototype space structure.

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Title: Materials Processing Technology

Title: Materials and Electronics Technology

Budget Activity: 1. Technology Base

Last Year's  
Reported Plan

Current  
Plan

Milestones

--

Late FY 1987

Demonstration of prototype rocket nozzle materials based on in-situ reinforced ultra-fine composites with high thermal conductivity.

--

Late FY 1988

Demonstration of two robotic systems to demonstrate intelligent task automation.

Early FY 1986

Eliminated

Preliminary selection of high temperature bearing concepts.

Mid FY 1986

Eliminated

Apply flexible robot arm control scheme to ammunition resupply module.

f. Explanation of Milestone Changes: On the ceramic fiber programs compositions with superior thermal stability have been identified; however, processing of those compositions into fibers has not yet been accomplished. The silicon carbide whisker program has delayed scale-up for one year to better take advantage of the advances being made in the understanding of processing variables. The high temperature bearing program has been postponed until the underlying basic research on solid lubricants has been performed. Delivery of the DART Demonstrator has been slightly delayed due to difficulty in developing process parameters which allow fabrication of the dual alloy rotor. The flexible robot arm control scheme was transferred to the Army much earlier than originally anticipated. Demonstration of one robotic system was delayed by contact difficulties and the other was delayed so that further research could be performed.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: MPT-2

Program Element: #62712E

USDR&E Mission Area: 530

Title: Materials Processing Technology

Title: Materials and Electronics Technology

Budget Activity: 1. Technology Base

H. PROJECTS OVER \$7 MILLION IN FY 1987:

1. Project Description: This project includes the "second generation" technology base for a broad range of Services gallium arsenide (GaAs) applications and for the major GaAs program being managed by DARPA for the Strategic Defense Initiative Organization (SDIO); development of technology for tenth micron resolution semiconductor processing; and applications of biotechnology to production of broad-band electromagnetic countermeasure materials. The near-term emphasis is in the development of second generation, GaAs based solid state electronics. These efforts include bipolar and enhancement/depletion mode gate arrays, computer aided design (CAD) systems, and analog to digital converters capable of 8 bit resolution at a one gigahertz sampling rate. Process and device modelling programs will be expanded to provide increased support to the integrated circuit design and fabrication programs.

2. Program Accomplishments and Future Programs:

a. FY 1985 Accomplishments: The complementary junction field effect transistor (CJFET) memory cell in GaAs continued to provide impressive performance results due to the increased noise margin (resistance to memory errors) of this design: fully functional 1024 bit memories were fabricated with a record setting 47% yield for the best wafer processed; addition of cross-coupling resistors into the memory cell demonstrated the elimination of high energy proton induced memory upsets; and new cell designs were conceived that promise to overcome cosmic-ray induced memory upsets. A defect density of less than 100 per centimeter squared was achieved with metal-organic chemical-vapor-deposition (MO-CVD) for gallium arsenide-gallium aluminum arsenide (GaAs/GaAlAs) heterostructures. The latter advance permitted the first successful demonstration of a medium-scale integrated (MSI) circuit - a synchronizer that utilized 824 gates of the 1000 gate array.

Researchers successfully demonstrated that focussed ion beams may be used to perform implantation, patterning, and micromachining on thin films used with semiconductor circuits at a resolution better than 0.1 micron.

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Project: MPT-2

Program Element: #62712F

USDR&E Mission Area: 530

Title: Materials Processing Technology

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Budget Activity: 1. Technology Base

b. FY 1986 Program: Four thousand gate arrays are being implemented in both the heterojunction bipolar technology and the enhancement/depletion (E/D) technologies. Circuits that utilize at least 80% of the gate array are being automatically routed by the computer aided design (CAD) under development.

Process modeling, with the end goal of producing a gallium arsenide (GaAs) version of the Stanford University Process Emulation Model (SUPREM), is beginning to make comparisons with experimental results.

The capability to use focused beams of electrons, photons, and ions to locally modify integrated circuits is being pursued by the design and fabrication of sophisticated novel devices and large scale integrated circuit components featuring patterns having geometries smaller than 500 nanometers.

c. FY 1987 Planned Program and Basis for 1987 Request: Device development efforts in second generation, high speed GaAs device technology and process modelling will continue. Basic materials and processing improvements that were achieved in prior years' work on the 61101E program element will be incorporated into practical device and integrated circuit structures to demonstrate useful components. The 8 bit, one gigasample analog to digital (A/D) converter will have all of its sub-elements fabricated and evaluated.

Efforts to use focused electron, photon and ion beams to locally modify integrated circuits will continue with an emphasis on the integration of all three beam processing technologies into a single enclosure, integrated circuit fabrication module.

Advances in biotechnology have progressed rapidly so that applications issues will be addressed. In this area, work with novel, self organizing, polymerizable lipid structures will focus on structural stability, dimensional control, and enhancement of electrical conductivity to produce broad-band electromagnetic countermeasure materials.

# FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: MPT-2

Program Element: #62712E

USDR&E Mission Area: 530

Title: Materials Processing Technology  
 Title: Materials and Electronics Technology  
 Budget Activity: 1. Technology Base

d. Program to Completion: This effort is a continuing one due to the exceptional importance of information and signal processing capabilities to defense systems. While initial gallium arsenide (GaAs) developments have emphasized radiation hardness the second generation will be applied to high speed DoD needs in electronic warfare. Work with novel self-organizing polymerizable lipid/protein structures will be vigorously explored because of significant anticipated applications as countermeasure materials, as important optically-active composite structures, as critical elements in both separation and fermentation technology, as novel vectors for large scale deoxyribonucleic acid (DNA) transfer in biotechnology, and as active and passive structures for sensor technology.

Opto-electronic processing capability will be advanced to develop concepts in which electronics handles the switching and optics handles the high speed transfer of multiplexed data. This program will develop the packaging technology necessary to incorporate this emerging capability into subsystems which can benefit from the noise immunity, wide bandwidth, Electro-Magnetic Pulse (EMP) immunity, and the ease of fanout offered by the optoelectronics.

e. Milestones: The milestones reported in last year's FY 1986 Descriptive Summary have been completed or are expected to be completed on schedule except as noted below:

<u>Last Year's Reported Plan</u>	<u>Current Plan</u>	<u>Milestones</u>
Mid FY 1986	Mid FY 1986	A 4 kilobit complementary Junction Field Effect Transistor (JFET) gallium arsenide (GaAs) random access memory with .2 microwatt power dissipation per bit will be demonstrated.
--	Late FY 1987	A ring oscillator and a flip-flop will be designed and fabricated using the maskless focussed ion beam process.

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Title: Materials Processing Technology  
 Title: Materials and Electronics Technology  
 Budget Activity: 1. Technology Base

Last Year's  
Reported Plan

Current  
Plan

Milestones

End FY 1986

Early FY 1988

GaAs analog to digital (A/D) converter with  
 gigahertz sampling rate will be fabricated.

f. Explanation of Milestone Changes: Contracting delays and the magnitude of the technical difficulty in realizing an 8 bit 1 gigasample per second analog to digital (A/D) converter delayed and stretched out this program.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #62714E  
USDR&E Mission Area: 530

Title: Nuclear Monitoring  
Budget Activity: 1. Technology Base

A. RESOURCES (\$ in Thousands)

Project Number	Title	FY 1985 Actual	FY 1986 Estimate	FY 1987 Estimate	FY 1988 Estimate	Additional to Completion	Total
							Estimated Costs
TOTAL FOR PROGRAM ELEMENT							N/A
		\$18,158	\$19,500	\$19,400	\$24,400	Continuing	

B. BRIEF DESCRIPTION OF ELEMENT AND MISSION NEED: The Nuclear Monitoring program conducts research and development to enhance U.S. capabilities for monitoring nuclear explosions. The program also provides technical information needed for developing sound national policy for negotiations on treaties limiting nuclear testing and provides technical support for U.S. participation in treaty-related international activities. In the event that a Comprehensive Test Ban Treaty, or a low-level Threshold Test Ban Treaty, were to be negotiated, U.S. security would require the highest possible level of monitoring capability to verify that the Soviets were complying with the provisions of such a treaty and not conducting clandestine tests under conditions designed to evade detection. In particular, better technical understanding is required to assess the monitoring value of stations internal to the USSR, high frequency seismic wave, propagation and on-site inspection procedures. The need for the nuclear monitoring program is further exemplified by the unexpected initiation of negotiations for an explosion yield threshold treaty in 1974, requiring the development (in a period of less than a year) of special monitoring provisions for the Peaceful Nuclear Explosion Treaty (PNET). The current uncertainty surrounding possible Soviet violations of the Threshold Test Ban Treaty yield limit has clearly brought to the forefront the need for an improved technical basis for monitoring of this treaty. The research program continues to provide key technical support to U.S. efforts in the United Nations Conference on Disarmament; particularly in the development of an International Seismic Data Exchange System for global treaty monitoring. Other research efforts in this program are aimed at developing the sensors and advanced technology needed to detect the presence of nuclear materials at remote distances.

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Program Element: #62714E  
USDR&E Mission Area: 530

Title: Nuclear Monitoring  
Budget Activity: 1. Technology Base

The FY 1987 nuclear monitoring program will pursue: development and evaluation of an advanced seismic array in Norway to determine the contribution of such systems to verifying future test ban treaties; technical support of international cooperative measures for verifying future test ban treaties; development and evaluation of advanced seismic data analysis methods for detecting and analyzing signals produced by advanced sensor systems; fundamental research into the physical characteristics of earthquake and explosion sources with particular emphasis on discrimination; and the exploration of sensing technology and diagnostic techniques to remotely detect the presence of nuclear materials and to provide nuclear diagnostic characterization of detected nuclear materials.

C. COMPARISON WITH FY 1986 DESCRIPTIVE SUMMARY: No significant changes.

D. OTHER APPROPRIATION FUNDS: Not Applicable.

E. RELATED ACTIVITIES: Complementary research is conducted by the National Laboratories of the Department of Energy and by the Air Force Technical Applications Center. These efforts are coordinated through existing interagency agreements and periodic working level coordination meetings.

F. WORK PERFORMED BY: Approximately 68% of this work is performed by industrial contractors, 15% in-house laboratories, 9% foreign, and 8% university. Major performers include: Teledyne Geotech, Garland, Texas and Alexandria, Virginia; Sierra Geophysics Inc., Seattle, Washington; S-Cubed, La Jolla, California; Lockheed Palo Alto Research Laboratory, Palo Alto, California; Science Applications, Inc., McLean, Virginia; Science Horizons Inc, Encinitas, California; NTNF/NORSAR, Kjeller, Norway; the University of Florida, Gainesville, Florida; Columbia University, New York, New York; University of Maryland, College Park, Maryland; the U.S. Geological Survey, Golden, Colorado; Lawrence Livermore National Laboratory, Livermore, California; Sandia National Laboratories, Albuquerque, New Mexico, and Los Alamos National Laboratory, Los Alamos, New Mexico.

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Program Element: #62714E  
USDR&E Mission Area: 530

Title: Nuclear Monitoring  
Budget Activity: 1. Technology Base

G. PROJECTS LESS THAN \$7 MILLION IN FY 1987: Not Applicable.

H. PROJECTS OVER \$7 MILLION IN FY 1987:

1. Project Description: The program objective is to improve the U.S. capability in yield estimation of the nuclear tests of other nations, to improve the detection, location, and discrimination of earthquakes and explosions. This project provides the fundamental research and development which is required to improve the detection of any nation's nuclear tests, and to estimate their yields. The project also provides the scientific support to international nuclear test ban efforts in which the U.S. is involved, such as those sponsored by the Conference on Disarmament.

2. Program Accomplishments and Future Programs:

a. FY 1985 Accomplishment: Yield Estimation. Laboratory experiments, finite difference calculations and analysis of field data improved our ability to predict coupling to and propagation of underground nuclear test energy in the earth, and to allow for effects of non-uniform propagation and of cratering. Improvements were made in the estimation of the contamination by tectonic strain release of long-period signals from underground explosions. These efforts improved our capability to estimate Soviet yields.

Data Acquisition. A high-frequency seismic array was installed in Norway in a joint effort with the government of Norway. The resulting data will greatly aid yield estimation and event detection and discrimination and will provide much needed data for additional research in these areas. Several long-term instrument development projects were completed. These new instruments can improve signal detection in noisy environments. Instruments were installed in the People's Republic of China (PRC) with the cooperation of the PRC. They will improve our yield estimation and our discrimination capability. Analysis of ocean-bottom and bore-hole seismometers showed that the borehole noise level was similar to that at a typical continental quiet site.

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Discrimination of Earthquakes from Explosions. Several promising new techniques to discriminate small magnitude events have been successfully applied to digital data from events which could not be otherwise identified. Theoretical and empirical studies continued on the difficult problem of regional discrimination. An empirical-statistical study was made of the hide-in earthquake evasion technique.

A large global experiment was conducted under the auspices of the United Nations, Conference on Disarmament (CD), to test and evaluate procedures to be employed by an International Data Exchange System. An International Data Center was established in Washington, D.C. to receive and analyze the data from this experiment. A number of recommendations and evaluations are being prepared for the CD on these results and for a future international monitoring system.

Two space experiments for x-ray imaging and testing new gamma ray detector materials were prepared for shuttle launch in early 1986.

b. FY 1986 Program: Yield Estimation. Laboratory experiments and finite difference calculations are continuing in order to understand explosion energy coupling in jointed and fractured rock. An underground test at the Nevada Test Site is to be detonated in rock believed to be very similar to that at the Soviet Test Site. A detailed effort to predict precise yields at a number of major Soviet Test Sites is underway. Finite difference modelling calculations in conjunction with detailed measurements of field teleseismic data are giving more accurate estimates of yield for Soviet explosions. Several DARPA-developed yield estimation techniques have been developed and evaluated so that they can be transferred to the Air Force Technical Applications Center for operational use.

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Data Acquisition. Data from the small array in Norway (NORESS) are being analyzed in its first year of operation with an emphasis on the detection of small explosions and on the reception of high frequency seismic waves which may be of use to detect decoupled explosions. Data from large industrial chemical explosions in the USSR are being analyzed to develop techniques to distinguish them from nuclear events. A program has been initiated to design an advanced array signal processing system using Artificial Intelligence to assess the data from the array. Such a system will be able to automatically detect, locate and classify seismic events in the vicinity of the array down to a very small magnitude.

Data from an ocean-bottom borehole seismometer deployed off the coast of Kamchatka is being analyzed to see how such seismometers can aid regional discrimination of explosions from earthquakes in the most highly active seismic (earthquake) region of the USSR.

Discrimination of Earthquakes from Explosions. Laboratory and theoretical approaches to regional propagation, especially high-frequency propagation are being emphasized in order to lay a firm foundation for empirical studies of discrimination and yield estimation. A careful study of empirical data on cavity decoupling is continuing. A study of discrimination between quarry blasts and earthquakes in the uniquely well-instrumented area of San Francisco is underway.

Support of International Negotiations. The results from U.S. participation in a large scale test of an international monitoring system sponsored by the United Nations Group of Scientific Experts are being analyzed to provide a firm basis for estimating the verification capability international systems might provide, and the resources required to establish such systems.

Nuclear Materials Detection. Increased emphasis is placed on development and testing of sensors for nuclear materials detection. This focusses on a planned experiment on the Space Shuttle. This experiment is ranked the number one priority by the Tri-Service Space Test Program Review Committee. Final design for a space-borne imaging detector array is being completed to assess application in detection.

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Evaluation of three different experimental approaches to detection is also underway.

c. FY 1987 Planned Program and Basis for FY 1987 Request: In yield estimation we will evaluate the results of a DARPA-initiated underground nuclear test at the Nevada Test Site in rock similar to that at the Soviet Test Site. This should lead to better estimates of the calculated bias adjustment between Soviet and U.S. seismic magnitudes for events of the same yield. Supporting laboratory and finite difference calculations will deepen our understanding of these results allowing for more suitable government decision making with respect to possible Soviet violations of the Threshold Test Ban Treaty. Installation will begin of a magnitude estimation system, based on DARPA research, by the Air Force which will give yield estimates directly from recorded waveforms. Discrimination will be enhanced by installation of an interactive graphics system which will implement short-period focal plane and first motion analysis, as developed by DARPA researchers, which can be used as a discriminant at the lowest magnitudes. For the smallest, shallow, perhaps decoupled, explosions only regional phases can be used as discriminants. Thus laboratory, theoretical, and empirical studies of regional discrimination will continue; as will studies on detection in the face of improved methods of decoupling. Data from the new seismic array configuration in Norway will be fully available. Intensive analysis of this data should provide important discoveries in yield estimation, detection of very small events, regional seismic propagation, possibly even within the Soviet Union, and especially at high frequencies where decoupling is inefficient. DARPA will continue to support additional treaty-related studies as required by international negotiations.

Development of nuclear materials detection technology will emphasize on extreme sensitivity and new imaging techniques will move us toward our goal of developing and demonstrating the capability to detect.

d. Program to Completion: The research program has provided several options for improving the verification of the Threshold Test Ban Treaty and a comprehensive test ban treaty. The seismic research requirements in future years will be driven by negotiation options as they appear. We anticipate that these programs in yield estimation, and in regional discrimination will be conducted at a level to support policy initiatives in this area. Because of the element of possible evasion by foreign

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Title: Nuclear Monitoring  
Budget Activity: 1. Technology Base

nations, the program is a continuing one since discrimination of natural seismic events from weak signals and/or decoupled explosions as seen at regional distances will require theoretical, experimental, and systems capabilities not yet established.

Continued development of nuclear materials detection technology with emphasis on extreme sensitivity and new imaging techniques will move us toward our goal of developing and demonstrating the capability to detect.

## e. Milestones:

<u>Last Year's Reported Plan</u>	<u>Current Plan</u>	<u>Milestones</u>
Late FY 1985	Late FY 1986	Complete U.S. participation in Conference on Disarmament technical data exchange experiments.
Late FY 1985	Mid FY 1986	Space Shuttle test of Advanced Gamma-Ray Detector.
Late FY 1985	Mid FY 1986	Space Shuttle test of high energy X-Ray imaging methods.
--	Late FY 1986	Statistical magnitude: advanced yield determination system completed and transferred to the Air Force.
--	Late FY 1986	Development of improved magnitude yield and discrimination regional parameters from theoretical calculations.

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Title: Nuclear Monitoring  
 Budget Activity: 1. Technology Base

<u>Last Year's Reported Plan</u>	<u>Current Plan</u>	<u>Milestones</u>
--	Early FY 1987	Evaluation of advanced seismic array technology in Norway.
--	Early FY 1988	Demonstration and Evaluation of array signal analysis techniques.

f. Explanation of Milestone Changes: The delay in completing the evaluation report to the Conference on Disarmament is due to the decision by that multilateral group to have a more detailed report than was originally planned. The delay in completing the Space Shuttle experiments in late FY 1985 is due to changes in the Space Shuttle launch schedule which are unrelated to this project.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #63226E  
USDR&E Mission Area: 530

Title: Experimental Evaluation of Major Innovative Technologies  
Budget Activity: 2. Advanced Technology Development

A. RESOURCES (PROJECT LISTING): (\$ in Thousands)

Project Number	Title	FY 1985 Actual	FY 1986 Estimate	FY 1987 Estimate	FY 1988 Estimate	Additional to Completion	Total Estimated Costs
TOTAL FOR PROGRAM ELEMENT		173,692*	177,179*	172,600*	168,753*	Continuing	TBD
EE-2	TEAL RUBY Experiment	30,750	27,535	10,000	5,000	0	240,864
EE-3	X-Wing/RSRA	5,900	4,300	7,500	0	0	78,561
EE-9	X-29 Advanced Technology Demonstrator	13,600	7,400	1,000	1,000	0	131,504
EE-16	Long Range Aircraft Interceptor Experiment	0	12,000	15,000	30,000	60,000	117,000
EE-17	Detection of Aircraft (HI-CAMP)	0	4,010	3,100	3,000	2,000	12,110
EE-18	Advanced Undersea Vehicle	0	11,100	18,500	20,000	15,000	62,971
EE-19	Advanced Cruise Missile Technology	0	4,797	20,000	15,000	10,000	52,326
EE-20	Autonomous Land Vehicle	0	0	0	10,000	60,000	70,000
EE-21	Armor/Anti-Armor	0	0	0	30,000	80,000	110,000
EE-22	Naval Battle Management	0	0	0	6,900	60,000	66,900

\* Total includes classified projects not identified herein.

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Program Element: #63226E  
USDR&E Mission Area: 530

Title: Experimental Evaluation of Major Innovative Technologies  
Budget Activity: 2. Advanced Technology Development

B. BRIEF DESCRIPTION OF ELEMENT AND MISSION NEED:

**TEAL RUBY Experiment:** This is a space experiment to demonstrate infrared detection of strategic aircraft from a space platform, measure target and clutter background signatures from space, and demonstrate advanced infrared mosaic detector technology. Expansion of the basic sensor missions is being investigated to include collecting signature measurements on other critical targets such as spacecraft, key tactical targets, ships and strategic missile plumes. The sensor and the associated USAF spacecraft are being built for FY 1986 launch by the space shuttle from Vandenburg Air Force Base.

**X-Wing/RSRA (formerly Helicopter Technology Demonstration):** This program is a major innovation in Vertical Takeoff and Landing aircraft design which, by stopping the rotor in flight, combines the vertical lift efficiency of a helicopter with the speed, range, and altitude performance of a transonic fixed wing aircraft. Design analysis indicates an operational X-Wing vehicle would have approximately three times the speed, range, and altitude performance of a conventional helicopter with equivalent payload lifting capability. These characteristics enable a very broad operational applicability such as: more flexible sea-basing for the Navy for conducting long range anti-submarine warfare; over-the-horizon targeting of surface and air targets; tactical jamming; close air support; and intra-theater self-deployment capability.

**X-29 Advanced Technology Demonstrator:** The X-29 Advanced Technology Demonstrator program is designed to develop and demonstrate advanced aerodynamics, structures and flight control technologies. This aircraft, made possible with advanced composite structure and a digital fly-by-wire flight control system, is being flight tested to investigate and quantify the technical benefits and performance capabilities of such an integrated advanced technology vehicle. Flight test are expected to develop confidence in numerous individual technologies, made them available as viable design options for advanced tactical aircraft and greatly reduce the risk, time and cost associated with future applications.

**Long Range Aircraft Interceptor Experiment:** The focus of this program is on the development of technology for a non-nuclear weapon that has potential for a dramatic advancement in anti-war warfare and features:  
(1) very short travel time, (2) very large attack footprint which limits defense avoidance (or electronic

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #63226E  
USDR&E Mission Area: 530

Title: Experimental Evaluation of Major Innovative Technologies  
Budget Activity: 2. Advanced Technology Development

countermeasures), (3) high mobility and flexible basing (air, ship or ground launch options), (4) difficult detection by the enemy that attack is under way, (5) high potential for covert use, particularly against an unsophisticated opponent, (6) large radar homing sensor and large kinematic footprint (7) multiple operating modes (home-on-jam, anti-radiation-homing, active search), and (8) mission flexible and adaptable as a fast reaction "gap filler" as new threats emerge or as unforeseen crisis situations arise.

Detection of Aircraft (HI-CAMP): This project includes the determination of the Infrared (IR) signatures of: (1) strategic aircraft (primary target), (2) ground and sea targets; and (3) the natural and perturbed backgrounds against which these targets are observed from a spaceborne or airborne IR surveillance sensor. This project will provide the data base for the design of advanced space surveillance systems and will guide the development of the technology base. The HI-CAMP (Highly Calibrated Airborne Measurements Program) II effort was initiated in FY 1981 to provide the above IR signatures through airborne measurements aboard a U-2 aircraft and to support the mission planning and flight operations of the TEAL RUBY Experiment (Project EE-02). HI-CAMP II includes the development, fabrication and flight test of a new, improved version of the highly successful HI-CAMP I infrared sensor system. The HI-CAMP II sensor was developed to include: (1) a stabilized sensor platform (improved by a factor of ten), (2) a new hybrid silicon detector/multiplexor chips (one for short and one for long wavelength), (3) the focal plane drive electronics, (4) modified platform and, (5) a new correlation tracker subsystem for tracking lower contrast targets. The improved gimbal system permits long atmospheric slant path observations.

Advanced Undersea Vehicle: The objective of this project is to develop and demonstrate advances in technology required for autonomous undersea vehicles.

Advanced Cruise Missile Technology: Improving Warsaw Pact cruise missile defenses require that future generations of these weapons possess substantially improved penetration capability and lethality. In addition, during FY 1985 increased attention has been given to two additional objectives: (1) precision non-nuclear attack and (2) location and identification of mobile targets. The Advanced Cruise Missile program is developing, in parallel, the two major elements of advanced propulsion and vehicle

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #63226E  
USDR&E Mission Area: 530

Title: Experimental Evaluation of Major Innovative Technologies  
Budget Activity: 2. Advanced Technology Development

design concepts to greatly improve survivability, lethality and range-payload. Critical component technologies are being developed and the program focus is on achieving a major advance in propulsion technology.

C. COMPARISON WITH FY 1986 DESCRIPTIVE SUMMARY:

The increase in FY 1986 estimate is largely the result of a increase in a classified program which was partially offset by the decrease in the X-Wing/RSRA program caused by the deletion of the high power transmission test vehicle from the program. The decrease in this FY 1987 request is the result of the rescoping of programs dictated by FY 1987 fiscal constraints.

D. OTHER APPROPRIATION FUNDS: Not applicable.

E. RELATED ACTIVITIES:

TEAL RUBY Experiment: The TEAL RUBY Experiment provides the transition of DARPA concept, technology and design data into a variety of future space systems being considered by the Air Force, Navy and Army. TEAL RUBY will provide global background data, target signature data (for band selection) and validation of the mosaic concept for the Air Force Advanced Warning System, the Navy Integrated Tactical Surveillance System (ITSS), Air Force Space Based Surveillance System (SBSS) and the Space Based Laser. The TEAL RUBY international cooperation effort, which includes joint experiments with Canada, Australia and the United Kingdom, has been formulated and chartered under the Technical Cooperation Program (TCP) (Subgroup J-Infrared) in order to facilitate the joint experiments and to exchange data in cooperative defense areas.

X-Wing/RSRA: The Helicopter Technology Demonstrator development is a derivative of Circulation Control Rotor work performed by the David Taylor Naval Ship Research and Development Center and also utilizes Army research into stopped rotor dynamics and control work. A joint DARPA/NASA convertible turbofan/shaft engine program has been conducted in a parallel effort to provide a new and more efficient propulsion system for this program.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #63226E  
USDR&E Mission Area: 530

Title: Experimental Evaluation of Major Innovative Technologies  
Budget Activity: 2. Advanced Technology Development

X-29 Advanced Technology Demonstrator: A DARPA/Air Force Memorandum of Agreement was signed for the Air Force Systems Command to act as the DARPA agent responsible for procurement and technical monitoring of the design and fabrication effort. The Air Force Program Office will also address the military utility of the numerous X-29 advanced technologies and their importance to the Services, advanced flight vehicle programs and especially the Advanced Tactical Fighter. The X-29 program exploits and extends research in the use of advanced composite materials, computer aided design, advanced aerodynamic and structural analytical design methods, and digital flight control design techniques previously conducted by the Air Force, Navy, NASA and industry. A DARPA/NASA Memorandum of Agreement was signed for NASA Ames, Dryden Flight Research Facility to conduct the flight test phase of the X-29 program. Also, NASA Langley has conducted structural dynamic testing and high angle of attack and spin wind tunnel testing to determine the aerodynamic coefficients and stability derivatives to use in Air Force, NASA and contractor ground simulations of the planned flight vehicles. In order to more rapidly transition the X-29 technologies, DARPA has formed the X-29 Future Applications Committee composed of potential corporate and government users to receive real-time results from the program so that results and lessons learned can be factored into other programs.

Long Range Aircraft Interceptor Experiment: This work is related to programs of the Air Force Ballistic Missile Office, the Naval Surface Weapons Center, and the Naval Ocean Systems Center. A joint technology demonstrator flight test program is being conducted with the Sandia National Laboratory.

Detection of Aircraft (HI-CAMP): These efforts are related to other programs of the following service units: Air Force: Directorates of Space Systems and Command, Control, Communications; Aeronautical Systems Division; Rome Air Development Center; Space Division; Air Force Geophysics Laboratory; Army: U.S. Missile Command; and the National Aeronautics and Space Administration (NASA).

Advanced Cruise Missile: The Advanced Cruise Missile Program is directly related to programs managed by the Joint Cruise Missile project office and the Air Force Aeronautical Systems Division, Deputy for Systems and Deputy for Development planning. The engine developments are related to small engine research at the Air Force Aeropropulsion Laboratory, the Army Tank and Automotive Command and the Naval Air Propulsion Center.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #63226E  
USDR&E Mission Area: 530

Title: Experimental Evaluation of Major Innovative Technologies  
Budget Activity: 2. Advanced Technology Development

F. WORK PERFORMED BY:

TEAL RUBY Experiment: The TEAL RUBY effort is performed by industry (76%), government in-house laboratories (15%), and by a Federal Contract Research Center (FCRC) (9%). Rockwell International, Seal Beach, California, is the prime contractor on the TEAL RUBY sensor; support contractors are: Logicon, San Pedro, California; Magnavox, Torrance, California; MRJ, Fairfax, Virginia; Riverside Research Institute, Arlington, Virginia; the Environmental Institute of Michigan, Ann Arbor, Michigan and E-Systems, Arlington, Virginia. The FCRC support is provided by the Aerospace Corporation, El Segundo, California. The program is managed by the Air Force Space Division, Los Angeles, California, with support in Naval areas of interest by the Naval Ocean System Center, San Diego, California. Target support is provided by the Air Force Geophysics Laboratory (AFGL), Hanscom AFB, Massachusetts and operational support will be provided by the Air Force Satellite Control Facility at Sunnyvale, California.

(U) X-Wing/RSRA: About 90% of the X-Wing program is being performed by industry. The prime contractor is Sikorsky Aircraft Company, Stratford, Connecticut. 10% of the work is being conducted by the David Taylor Naval Ship Research and Development Center, Carderock, Maryland and the Army Aviation Research and Development Command, Ft. Eustis, Virginia. NASA Ames Research Center is supporting the program through wind tunnel testing and flight research.

X-29 Advanced Technology Demonstrator: Prior to the delivery of the X-29 to the government approximately 90% of the effort was performed by industry. The principal contractor was Grumman Aircraft Corporation, Bethpage, New York. Approximately 10% was being performed in-house by the Air Force Systems Command and by numerous NASA centers. The NASA and Air Force percentage have increased to a much larger share as the flight test phase started. The technical agent responsible for program oversight is the Air Force Wright Aeronautical Laboratories, Flight Dynamics Laboratory, assisted by NASA Ames, Dryden Flight Research Facility and the Air Force Flight Test Center, Edwards AFB, California. The Navy has continued to support the logistics and technical development with engineering support from the Naval Air Test Center, Patuxent River, Maryland.

Long Range Aircraft Interceptor Missile: About 90% of the effort is conducted by industry. The major contractors are: Decision Science Applications, Arlington, Virginia; Hughes Aircraft Company, Fullerton and Canoga Park, California; Raytheon Company, Lexington, Massachusetts; Lockheed Missiles and Space

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #63226E  
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Budget Activity: 2. Advanced Technology Development

Company, Palo Alto, California; and Science Applications, Incorporated, La Jolla, California. The major integrator for this project is Sandia National Laboratory, Albuquerque, New Mexico.

Detection of Aircraft (HI-CAMP): Approximately 95% of this work is performed by industry and 5% by government laboratories. Major industrial contractors are: Lockheed Missile and Space Company, Palo Alto, California; MRJ, Fairfax, Virginia; Photon Research, LaJolla, California; and ERIM, Ann Arbor, Michigan. Government laboratories include: Air Force Geophysics Laboratory, Hanscom Air Force Base, Massachusetts; the Naval Ocean Systems Center, San Diego, California; and the National Aeronautics and Space Administration. Federal Contract Research Center support includes that of the Aerospace Corporation, El Segundo, California and the Institute for Defense Analyses, Arlington, Virginia.

Advanced Undersea Vehicle: Approximately 90% of the effort is performed by industry and 10% by government laboratories. The major contractors are Scientific Research Laboratories, Santa Barbara, California and Rockwell International, Anaheim, California. The government laboratories which support this project are the David Taylor Naval Ship Research and Development Center, Carderock, Maryland, and the Naval Underwater Systems Center, Newport, Rhode Island.

Advanced Cruise Missile Technology: Industry provides approximately 98% percent of the effort for this program and government laboratories the remaining 2%. LTV Aerospace, Dallas, Texas is the prime contractor with engine demonstration support from the Institute for Defense Analyses, Arlington, Virginia.

G. PROJECTS LESS THAN \$7 MILLION IN FY 1987:

X-29 Demonstrator: DARPA has joined the Air Force and NASA to extend the previously planned flight testing to include high angle of attack investigation. The second X-29 demonstration is being modified to accomplish this testing. The funds in FY 1987 will augment that of the Air Force and NASA to accomplish the testing and transition of the X-29 program to the Air Force.

HI-CAMP: In FY85 under program element 62301E, Project ST-6, The High Resolution Calibrated Airborne Measurements Program (HI-CAMP) II system completed development flight testing and began operational

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #63226E  
USDR&E Mission Area: 530

Title: Experimental Evaluation of Major Innovative Technologies  
Budget Activity: 2. Advanced Technology Development

flights for the collection of infrared (IR) data on targets and backgrounds. Operational flights were conducted against many targets, including target aircraft, helicopters, aircraft (F-14's) taking off from airfields and aircraft carriers, and tactical Army targets. HI-CAMP also collected data in support of the Strategic Defense Initiative (SDI). Some of the flights made in FY85 were funded by the Air Force, Navy and SDI. A US - United Kingdom (UK) cooperative flight series was also made with UK and US targets over land and sea in the area of the US. In FY 1986 this program transitions to Program Element 63226E, Project EE-17 and will focus on support of the major DARPA/Air Force TEAL RUBY Satellite Experiment. HI-CAMP has the same primary infrared spectral bands as the TEAL RUBY sensor but with higher resolution. HI-CAMP will be used to collect simultaneous truth background and target data during the TEAL RUBY experiment to help in experiment diagnostics and for calibration purposes. Target missions will include aircraft, tactical and strategic missiles, ships, and tactical Army targets. HI-CAMP efforts in support of TEAL RUBY will continue for the life of TEAL RUBY. In FY87 HI-CAMP will be used to address the development and demonstration of technologies relevant to the detection and interception of enemy strategic aircraft and missiles. Other missions will be flown for the Army, Navy, Air Force dependent on sensor/aircraft availability.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: #EE-2

Program Element: #63226E

USDR&E Mission Area: 530 (TIARA)

Title: TEAL RUBY Experiment

Title: Experimental Evaluation of Major Innovative Technologies

Budget Activity: 2. Advanced Technology Development

H. PROJECTS OVER \$7 MILLION IN FY 1987:

1. Project Description: DARPA initiated the TEAL RUBY Program in 1974 to demonstrate the feasibility of detecting strategic air vehicles using a space-based infrared sensor and to provide a future option for warning of bomber attack against North America or Naval Battle Groups. Detection of weak aircraft signatures against the strong earth background clutter required a large number of advanced technologies, with the most critical being infrared detectors. The sensor is designed with sufficient sensitivity to detect various targets. Joint missions with Canada, Great Britain and Australia have been formulated over tropical backgrounds for aircraft, missile and ship targets. These countries are major participants in the TEAL RUBY and DARPA HI-CAMP Air Vehicle Detection programs and have technical and military personnel as full time members in the TEAL RUBY program office. Infrared background measurements, required for the design of future operational sensors, will be made on a worldwide basis and under a variety of climatological and geographic conditions. The agreements are in progress. On-orbit TEAL RUBY experiments will be performed to support the requirements of DARPA, Air Force, Navy, and Army.

2. Program Accomplishments and Future Program: In the design and development of the TEAL RUBY sensor, many technologies of great importance to future DoD systems have been significantly advanced. These advances include the development of light weight optical elements; a light weight space qualified cryostat; and manufacturing technologies. As the launch of TEAL RUBY approaches, the program emphasis has now shifted to understanding how the sensor performs based on radiometric testing; completing sensor/spacecraft integrated testing to meet the launch date and the development of the operational software and hardware to gather data on-orbit, process the data and interpret the results. These efforts are progressing satisfactorily. Hardware/software development and training for the operation of the Rockwell Mission Operations Center (MOC) is continuing and rehearsals for launch and on-orbit operations with the Satellite Control Facility have begun. Software development to support the MOC and data analysis continues to receive strong emphasis due to its criticality and complexity. The data analysis software is based upon the experience and software generated by the DARPA Highly Calibrated Airborne Measurements Program (HI-CAMP) sensor and will provide the basis for future systems analysis.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: #EE-2

Program Element: #63226E

USDR&E Mission Area: 530 (TIARA)

Title: TEAL RUBY Experiment

Title: Experimental Evaluation of Major Innovative Technologies

Budget Activity: 2. Advanced Technology Development

a. FY 1985 Accomplishments: In FY 1985, the TEAL RUBY flight sensor completed qualification acceptance testing and began radiometric chamber testing. The TEAL RUBY spacecraft successfully completed acoustic testing with the qualification sensor installed. Launch and on-orbit software development and demonstration continued. Independent validation and verification of software began. Final detailed on-orbit experiment planning began to support development of the TEAL RUBY Space Experiment Plan. Rehearsals were conducted at the Satellite Control Facility to exercise and complete development of on-orbit software as well as verify the operation of ground control and communication hardware.

b. FY 1986 Program: Radiometric testing of the TEAL RUBY flight sensor is being completed. The qualification sensor will be removed from the spacecraft and replaced by the flight sensor. Final integrated spacecraft/sensor systems test will be completed. The spacecraft system will be packaged and delivered for Shuttle integration and launch in late FY 1986 as the first Vandenberg Shuttle launch. After insertion into final orbit, the TEAL RUBY sensor will be checked out on orbit and experiment operations initiated. Experimental missions will be conducted for selected time periods corresponding to orbital passage over targets and/or background areas of interest. Experimental segments or missions are generally categorized as: (1) target missions demonstrating on-board detection; (2) background missions to record multispectral radiometric data; and (3) special experiments to provide specific critical data to support other important DoD programs. The Allied, Navy and other agency missions will be conducted after the first successful aircraft detection mission and will be fitted in between major aircraft deployment periods. All this planning will be established prior to launch and updated based on actual orbital data which will modify mission encounter periods. Focal plane operation will be monitored using a variety of temperature, signal and noise measurements using an on-board calibration unit and observation of calibration site. The estimated life, of the TEAL RUBY sensor is limited by the supply of stored liquid cryogen subject to actual usage rates on-orbit. Each set of mission data will receive a "quick look" for feedback to subsequent missions to increase the efficiency of collection over the lifetime of the TEAL RUBY sensor. A final experiment evaluation report will follow mission completion by approximately six months.

# FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: #EE-2  
 Program Element: #63226E  
 USDR&E Mission Area: 530 (TIARA)

Title: TEAL RUBY Experiment  
 Title: Experimental Evaluation of Major Innovative Technologies  
 Budget Activity: 2. Advanced Technology Development

c. FY 1987 Planned Program and Basis for FY 1987 Request: Based on the life of the TEAL RUBY sensor, on-orbit operations will continue. Target and background missions will continue to be run in accordance with the prelaunch space experiment plan revised to account for on-orbit sensor performance and/or modified requirements of the various TEAL RUBY data user communities. Each set of mission/experiment data will receive a "quick look" for feedback to upcoming missions to ensure the efficiency of data collection over the lifetime of the sensor. In depth data analyses of all mission/experiment data will begin. Detailed analysis of target data, background data and sensor technical performance parameters will be performed. The primary objective of these in depth analyses is to support the overall objective of TEAL RUBY--to demonstrate the feasibility of detecting strategic air vehicles using a space-based infrared (IR) sensor and thus a future option for warning of air vehicle attacks against North America or Naval Battle Groups. The ability to use a space-based IR sensor for sensing other strategic and tactical targets will also be assessed for the development of future IR systems. Additionally, a large worldwide infrared data base will be collected to support existing and future IR systems. Raw and processed data will be completely documented and stored in a library for the use of future systems designers.

d. Program to Completion: The launch of TEAL RUBY from the Space Shuttle will occur in late FY 1986. All reports will be completed. All the data will be processed into engineering research data tapes and put into a TEAL RUBY library for future system designers.

## e. (S) Milestones:

Last Year's Reported Plan	Current Plan	Milestones
Mid FY 1985	Early FY 1986	Flight sensor chamber test complete
Early FY 1986	Late FY 1986	Launch of P-80 Spacecraft. (AF Program P888)

FY 1987 DESCRIPTIVE SUMMARY

Project: #EE-2  
Program Element: #63226E  
USDR&E Mission Area: 530 (TIARA)

Title: TEAL RUBY Experiment  
Title: Experimental Evaluation of Major Innovative Technologies  
Budget Activity: 2. Advanced Technology Development

f. Explanation of Milestone Changes: TEAL RUBY will be launched on the 1st Vandenburg Air Force Base (VAFB) shuttle launch. The shuttle launch date for TEAL RUBY has slipped from October 1985 to July 1986. As a result, program completion will be delayed to allow processing of all raw data tapes into a form suitable for storage in an engineering library along with report documentation.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: #EE-3

Program Element: #63226E

JSDR&E Mission Area: #530

Title: X-Wing/RSRA

Title: Experimental Evaluation of Major Innovative Technologies

Budget Activity: 2. Advanced Technology Development

1. PROJECTS OVER \$7 MILLION IN FY 1987:

1. Project Description: The X-Wing vehicle will provide the Services with a vertical takeoff and landing circulation control, rotating wing helicopter that converts to fixed wing mode for forward flight at significantly increased efficiency and speed (300-400 Knots). The X-Wing concept, when developed into an operational vehicle, will have vertical takeoff and landing characteristics similar to those of conventional helicopters, (e.g., low disk loading which results in low "downwash"). However, the X-Wing would approach the dynamic characteristics of a high performance fixed wing combat vehicle in the stopped rotor configuration. Current helicopters have maximum forward speeds of approximately 180 knots and very low dynamic performance, i.e., turn rate, roll rate, rate of climb, etc. An X-Wing vehicle operating at over 350 knots would potentially exhibit more than three times the lift-to-drag ratio of conventional helicopters. At the same time, it would have the potential for improving range performance in the fixed wing mode by a factor of three. Fixed wing performance of the X-Wing can approach that of current high performance aircraft at high speeds but far exceeds the low speed performance of these same vehicles. The closest competitor is the Harrier which has limited dynamic performance in the low speed regime and has extremely high disk loading which is unacceptable for vertical landing on unprepared landing zones. Thus, the X-Wing vehicle concept offers significant efficiencies over both regimes of either a pure helicopter or a fixed wing high performance vehicle. The X-Wing concept embodies several major technical advances in aerodynamics, controls and structures. Aerodynamic lift is generated by 'Circulation Control' using tangential blowing of a thin sheet of air from a slot adjacent to a rounded trailing edge of a quasi-elliptical airfoil. Control of the rotor blade lift is produced by varying the blade duct pressure (hence the blowing) with pneumodynamic valving in the rotor hub...thus eliminating blade cyclic pitch control and permitting active load and vibration control (higher harmonic control). The structures technology is based upon the use of advanced graphite composite materials to achieve unprecedented blade stiffness levels and to avoid aeroelastic divergence. Objectives of this program are to demonstrate the feasibility and practicability of the X-Wing rotor concept through design, fabrication and flight test of a demonstration rotor. During FY 1983, a joint DARPA/NASA X-Wing rotor demonstration program using the Rotor Systems Research Aircraft (RSRA) was initiated with approximately equal funding from each agency. The NASA portion of the program is being conducted under the effort entitled: "Technology for Next Generation Rotorcraft" (within the Rotorcraft Systems Technology Program UPN 532), which began in FY 1984. The X-Wing/RSRA program is composed of the following major tasks:

## FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: #EE-3

Program Element: #632226E

USDR&E Mission Area: #530

Title: X-Wing/RSRA

Title: Experimental Evaluation of Major Innovative Technologies

Budget Activity: 2. Advanced Technology Development

(1) design and analysis; (2) basic design data; (3) fabrication of a large (56-foot diameter) rotor system; (4) ground tests and software development; and (5) contractor and NASA flight tests of the rotor using the RSRA. Contractor rotor system design activities are supported by the David Taylor Naval Ship Research and Development Center and NASA in-house programs of subscale wind tunnel testing and analytic correlation. Sophisticated Mach-scaled dynamic models built by both Boeing and Sikorsky have been utilized extensively to provide basic design data, particularly in the conversion (rotating to stopped) mode.

### 2. PROGRAM ACCOMPLISHMENTS AND FUTURE PROGRAMS:

a. FY 1985 Accomplishments: During FY 1985 the X-Wing rotor system was fabricated using primarily advanced graphite composite materials. The rotor blades represent the largest, most heavily loaded composite structures in existence and have substantially advanced the state-of-the-art in this area. The rotor hub and pneumatic control systems were fabricated and installed on the Propulsion System Testbed (PSTB), the major ground test rig for the program. An advanced flight compressor was also developed and tested during this period which exhibited a significant improvement in the state-of-the-art of compact diffusers. The drive system was successfully tested including transmissions, compressor and an advanced high power clutch. The latter demonstrated a significant state-of-the-art advance in the transfer of extremely high torque levels using a very lightweight mechanism. The X-Wing flight control system represents an advancement of fly-by-wire technology, in many respects exceeding the space shuttle flight control system in technical sophistication. During FY 1985, significant problems were encountered in the development of software for this system, requiring a stretch-out in the PSTB and flight test schedule. The Rotor Systems Research Aircraft testbed modifications needed for acceptance of the X-Wing rotor system were completed while the second RSRA vehicle completed flight envelope expansion testing at NASA's Dryden Research Center. A sophisticated Vehicle Management System Laboratory (VMSL) was completed to permit laboratory validation of the flight control system.

b. FY 1986 Program: Following PSTB testing of all dynamic components, the Rotor System Research Aircraft airframe is being tied down for initial integration system tests. Software and flight worthy avionics hardware is being installed in the Vehicle Management System Laboratory for final

# FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: #EE-3  
 Program Element: #63226E  
 SDR&E Mission Area: #530  
 Title: X-Wing/RSRA  
 Title: Experimental Evaluation of Major Innovative Technologies  
 Budget Activity: 2. Advanced Technology Development

validation prior to actual flight validation. Dynamic model testing is being completed. Initial flight testing of the RSRA begins in mid FY 1986, with continued testing throughout the balance of the year. Flight test objectives include investigation of: (1) the in-flight aerodynamics associated with the circulation control boundary layer control system; (2) the capability of the pneumatic control system to provide flight control, vibratory airload suppression and gust control, particularly during conversion to fixed wing flight; (3) the performance of the closed loop fly-by-wire stabilization and control system in all flight modes; (4) the structural and aeroelastic performance of the graphite composite fore/aft swept X-Wing blades; and (5) an operational air speed/altitude envelope up to the limits of the Rotor Systems Research Aircraft airframe.

c. FY 1987 Planned Program and Basis for FY 1987 Request: Upon review of flight test data and successful demonstration of X-Wing feasibility and practicability, the program will be transferred fully to NASA which will continue and complete experimental testing during FY 1987. During FY 1987, major flight milestones leading to NASA transition will include conversion from rotary wing to fixed wing (and reverse) and flight with higher harmonic adaptive vibration controls.

d. Program to Completion: Not applicable.

e. Milestones:

<u>Last Year's Reported Plan</u>	<u>Current Plan</u>	<u>Milestones</u>
Late FY 1985	Mid FY 1986	Ground testing; flight clearance review; conduct first flight.
Late FY 1985	Mid FY 1987	Flight test data review.
Late FY 1985	--	Fabricate, qualify and assemble major XCH-62 (HLH).
Mid FY 1986	Late FY 1987	NASA receipt of aircraft.

# FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: #EE-3  
 Program Element: #63226E  
 USDR&E Mission Area: #530  
 Title: X-Wing/RSRA  
 Title: Experimental Evaluation of Major Innovative Technologies  
 Budget Activity: 2. Advanced Technology Development

Late FY 1986	--	Initiate final XCH-62 (HLH) assembly functional tests and proof loading.
Mid FY 1987	--	Complete airframe final assembly.
Late FY 1988	--	Complete functional testing, proof loading, ground tests and first flight test.
Late FY 1989	--	Complete flight testing.

f. Explanation of Milestone Changes: During FY 1985, significant problems were encountered in software development, resulting in delays in integration into the Propulsion System Testbed and causing a slippage of the scheduled flight test. The last four milestones pertain to a plan to start a joint DARPA/Army/NASA heavy lift helicopter research program which was terminated by the Congress.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: #EE-16

Program Element: #63226E

USDR&E Mission Area: 530

Title: Long Range Interceptor Experiment

Title: Experiment Evaluation of Major Innovative Technologies

Budget Activity: 2. Advanced Technology Development

H. PROJECTS OVER \$7 MILLION IN FY 1987:

1. Project Descriptive: The Long Range Interceptor Experiment (LORAINÉ) transitioned from the Strategic Technology program element 62301E, Project ST-4, in FY 1986. Focus of the LORAINÉ program has been on development of technology for a non-nuclear very long range anti-aircraft weapon launched from ship, land, or air. The development is intended primarily for Naval battle group and Continental United States (CONUS) air defense applications. By having a large search area the LORAINÉ minimizes the need for accurate pretargeting information, and coupled with its speed of reaction eliminates the need for update information in most scenarios. It is ideally suited to complement long range surveillance systems such as Over-the-Horizon (OTH) Radar and Space Infrared (IR) systems. These systems can be used to cue the LORAINÉ. LORAINÉ can also be used to provide the outer air defense for Naval battle groups. The baseline reentry vehicle was developed by the Sandia National Laboratory.

2. Program Accomplishments and Future Programs: Efforts have been underway to resolve the demanding technical issues and operation. A nearly full scale LORAINÉ concept demonstration will be developed to culminate in one or two intercepts under nominal operating conditions. The program will include the development at near full power level; the attendant cooling system; an appropriate prime power source; and all hardware miniaturization necessary to incorporate the LORAINÉ system. The detailed LORAINÉ intercept program plan is being developed. However, it is currently anticipated that one or two controlled intercepts accomplished in the FY 1989-90 period.

a. FY 1985 Program: In FY 1985 a 600 nmi trajectory flight test was successfully conducted verifying electrical, mechanical, and thermal performance environment. This successful test, which was launched from the Barking Sands Missile Range facility on Kauai, Hawaii to the vicinity of Johnson Island, achieved a major milestone for the Long Range Interceptor Experiment (LORAINÉ) program. The comparisons of theoretical predictions and chamber data with trajectory and antenna performance telemetry data collected during the experiment were excellent. Remaining work in the fiscal year included detailed analyses of the data and preliminary planning for a full scale LORAINÉ intercept plan.

# FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: #EE-16

Program Element: #63226E

USDR&E Mission Area: 530

Title: Long Range Interceptor Experiment

Title: Experiment Evaluation of Major Innovative Technologies

Budget Activity: 2. Advanced Technology Development

h. FY 1986 Program: In FY 1986, development towards the full scale demonstration of the LORAINÉ is being initiated. This includes initial phase major contracts for components and supporting equipment. The principal objective of this phase, which extends to FY 1989, is to develop sufficiently robust algorithms to provide a high level of background clutter cancellation for the on-board radar to detect atmospheric targets. To meet this objective for realistic stressing environments both captive flight tests and a free flight test are planned. Data will be collected over diversified terrains and used to fully develop and demonstrate the clutter suppression which will be required for an on-board real time operational mode. The associated radar electronics will incorporate advanced technology for the conformal antenna and Monolithic Microwave Integrated Circuit Transmitter/Receiver (T/R) module designs. Full instrumentation will be included to verify electrical, mechanical, and thermal performance of the system.

c. FY 1987 Planned Program and Basis for FY 1987 Request: In FY 1987, the system design for the clutter test flights will be completed, and full up assembly of the monolithic T/R modules and antenna assembly is planned. System integration will begin during the fourth quarter in preparation for the FY 1988 - FY 1989 clutter tests.

d. Program to Completion: This is a continuing program. The evaluation of sensor/navigation techniques will be continued with full scale LORAINÉ flight test demonstration planned for the FY 1991 time frame.

## e. Milestones:

<u>Last Year's Reported Plan</u>	<u>Current Plan</u>	<u>Milestones</u>
Mid FY 1985	Mid FY 1986	Completed sub-scale flight test
Early FY 1986	Mid FY 1986	Complete Long Range Interceptor Experiment (LORAINÉ) flight test planning

# FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: #EE-16 Title: Long Range Interceptor Experiment  
 Program Element: #63226E Title: Experiment Evaluation of Major Innovative Technologies  
 USDR&E Mission Area: 530 Budget Activity: 2. Advanced Technology Development

Mid FY 1987	Late FY 1987	LORAINÉ clutter collection system integration begins
--	Late FY 1988	Captive flight clutter tests
--	Early FY 1989	Fly free flight clutter experiment
Mid FY 1987	Early FY 1990	Fly passive HOME ON JAM (HOJ) flight
Early FY 1988	Late FY 1990	LORAINÉ sensor integration completed
Early FY 1989	Mid FY 1991	LORAINÉ intercept of drone demonstration

f. Explanation of Milestone Changes: Initial milestones reported last year proved too aggressive. Schedule slippage has occurred due to late completion of subscale LORAINÉ test flight and reevaluation of future Long Range Interceptor Experiment (LORAINÉ) flight test requirements and technology road maps.

# FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: #EE-18

Program Element: #63226E

USDR&E Mission Area: 530 (TIARA)

Title: Advanced Undersea Vehicle

Title: Experimental Evaluation of Major Innovative Technologies

Budget Activity: 2. Advanced Technology Development

## H. PROJECT OVER \$7 MILLION IN FY 1987:

1. Project Description: The objective of this program is to develop and demonstrate advances in technology required for autonomous undersea vehicles. Previous efforts (thru FY 1985) were reported in Program Element 62702E and summary details are contained in Project TT-3.

## 2. Program Accomplishments and Future Programs:

a. FY 1985 Accomplishments: The FY 1985 portion of this program is reported in Program Element 62702E, Project TT-03.

b. FY 1986 Program: Demonstration of the design is being conducted in the Langley Tow Basin. Design and development is concluding. Efforts are being initiated advanced sensor systems. Mission studies are continuing which will identify alternate uses.

c. FY 1987 Planned Program and Basis for FY 1987 Request: Analysis of test bed vehicle requirements for integration and testing of these technologies will be completed in FY 1987. Test bed acquisition should begin in late FY 1987 with subsystem integration in early FY 1988.

d. Program to Completion: This is a continuing program.

## e. Milestones:

<u>Last Year's Reported Plan</u>	<u>Current Plan</u>	<u>Milestones:</u>
Early FY 1986	Early FY 1986	Begin advanced technology demonstrations
Late FY 1986	Late FY 1987	Complete critical on-going technology demonstrations
Late FY 1988	Late FY 1988	Demonstration of adaptive vehicle technologies

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: #EE-18

Program Element: #63226E

USDR&E Mission Area: 530 (TIARA)

Title: Advanced Undersea Vehicle

Title: Experimental Evaluation of Major Innovative Technologies

Budget Activity: 2. Advanced Technology Development

f. Explanation of Milestone Changes: Completion of technology demonstration has slipped approximately one year to allow completion of the mission studies and identification of alternate uses and their associated critical technologies.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: #EE-19

Program Element: #63226E

USDR&E Mission Area: #530

Title: Advanced Cruise Missile Technology

Title: Experimental Evaluation of Major Innovative Technologies

Budget Activity: 2. Advanced Technology Development

H. PROJECTS OVER \$7 MILLION IN FY 1987:

1. Project Description: The Advanced Cruise Missile Technology program is developing technologies applicable to next generation strategic and tactical missiles and reconnaissance systems. Major technical objectives are being conducted in conceptual designs needed to achieve a substantial increase in range-payload product. The increased engine thermal efficiency, or other high energy density fuels, low vehicle structural weight and blended wing/body supersonic aerodynamics are expected to produce either longer ranges or a reduction in volume and reduction in weight for fixed ranges but with significantly increased survivability. In the near term, successful development would enable retrofit of existing cruise missile propulsion units to achieve significant range increases. Such a retrofit for example, would increase the stand-off range of cruise missile carriers.

2. Program Accomplishments and Future Programs:

a. FY 1985 Accomplishments: During FY 1985, several major technical milestones were achieved. A 20-inch diameter carbon-carbon turbine stage was successfully operated at 100-percent stress design condition. This test demonstrated unprecedented structural capability for carbon-carbon as a primary load-carrying material and established its feasibility for future turbine engine combustion environment. A coated, simple geometry turbine blades were spin tested in a simulated engine combustion environment. A third accomplishment was the achievement of greater combustion efficiency. Together these achievements can produce significant increases in speed and altitude performance of advanced cruise missiles and reconnaissance systems. This effort was supported under Program Element No. 62301E, Project ST-5 in FY 1985.

# FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: #EE-19 Title: Advanced Cruise Missile Technology  
 Program Element: #63226E Title: Experimental Evaluation of Major Innovative Technologies  
 USDR&E Mission Area: #530 Budget Activity: 2. Advanced Technology Development

b. FY 1986 Program: Major focus is on the development of optimized coatings for the various components of turbine, stators and combustors. Additional effort is being concentrated on the development and characterization of advanced carbon-carbon materials for these components as well as development of an advanced weave architecture for lower cost turbine fabrication.

c. FY 1987 Planned Program and Basis for FY 1987 Request: Coated components (turbine, combustor and stator) will be fabricated and stress qualified. Processes for coating of complex three dimensional parts will be developed. A ceramic recuperator will be tested. The coatings technology requires a full interdisciplinary effort involving chemists, ceramicists, composite specialists, coatings process experts, photomicrography specialists, turbine stress analysts and combustion specialists. This team collectively will evolve a sophisticated coating technology base applicable to various components and segments of the turbine. Achievement of this coating milestone will represent a major advance in the national technology of future gas turbine engines.

d. Program to Completion: In FY 1988 and FY 1989 the component parts will be individually tested and then assembled into a complete turbine hot section which will then be tested. This demonstration will provide the basis for a future engine development having revolutionary capabilities.

## e. Milestones:

<u>Last Year's Reported Plan</u>	<u>Current Plan</u>	<u>Milestones</u>
Early FY 1986	--	Preliminary vehicle design concept and model testing initiated.
Mid FY 1986	--	Individual full scale engine and vehicle component fabrication and testing initiated.
--	Late FY 1986	Oxidation protection coating demonstration.

# FY 1987 RDT&E DESCRIPTIVE SUMMARY

Project: #EE-19  
 Program Element: #63226E  
 USDR&E Mission Area: #530  
 Title: Advanced Cruise Missile Technology  
 Title: Experimental Evaluation of Major Innovative Technologies  
 Budget Activity: 2. Advanced Technology Development

Late FY 1987	--	Vehicle configuration design defined and model testing completed.
Late FY 1987	--	Decision to initiate development of flight test vehicle.
--	Early FY 1987	Advanced fiber weave architecture demonstration.
--	Early FY 1988	Static coating data at maximum temperatures.
--	Mid FY 1987	Hot spin tests of turbine.
Early FY 1988	--	Initiate fabrication and integration of flight test vehicle subsystem.
--	Early FY 1989	Fabrication and buildup of turbine hot section.
Mid FY 1989	--	First flight test of full scale test vehicle.
Mid FY 1987	Late FY 1989	Validation of full scale engine components suitable for flight weight engine completed.

f. Explanation of Milestone Changes: The milestone changes reflect definitization of the program and significant restructuring to accommodate funding profiles.

# FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #63269E  
USDR&E Mission Area: #530

Title: National Aero-Space Plane Technology (NASP)  
Budget Activity: 1. Advanced Technology Development

## A. RESOURCES (Project Listing): (\$ in Thousands)

Project Number	Title	FY 1985 Actual	FY 1986 Estimate	FY 1987 Estimate	FY 1988 Estimate	Additional to Completion	Total Estimated Cost
	Total for Program Element		60,000	80,000	80,000	240,000	

## B. BRIEF DESCRIPTION OF ELEMENT AND MISSION NEED:

This program element contains all DARPA funds to be applied to the joint DOD-NASA National Aero-Space Plane (NASP) Technology Program. Supporting Air Force, Navy and SDIO funding are contained in their respective budgets. This element has been established by the Deputy Secretary of Defense in order to combine previous, on-going and future technology efforts into a single, easily traceable, consolidated funding line focused solely on the NASP advanced technology development. Prior DARPA efforts were funded from project ST-05 in PE 62301E. Other planned joint service support would have come from portions of many other 6.2 and 6.3 lines. The National Aeronautics and Space Administration is a joint participant in this program and has similarly established a focused technology effort in FY 1986.

The funding in this program element continues the investigation and development of advanced propulsion, structures, materials, aerodynamics and other critical technologies to the point where a decision can be made about the feasibility of building a vehicle which could be used both as a hypersonic aircraft and as a reusable single-stage-to-orbit launch vehicle. If the technological development validates that such a vehicle can be built, the program is planned to proceed to a flight test of an experimental research vehicle. These technologies and the results of a possible flight test will provide the basis for a new generation of responsive and affordable aircraft and space launch vehicles to satisfy both military and civilian needs. Significant benefits of a possible subsequent vehicle development program could be a highly advanced military aircraft, flexible basing, low-cost space launch, and civil hypersonic transports. DARPA will manage the technology validation phase with the program transitioning to Air Force management for the flight research vehicle phase. The joint executing technical office will be established at Wright-Patterson Air Force Base for both phases.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #63269E  
USDR&E Mission Area: #530

Title: National Aero-Space Plane Technology (NASP)  
Budget Activity: 1. Advanced Technology Development

C. COMPARISON WITH FY 1986 DESCRIPTIVE SUMMARY:

This is a new program element established by the Deputy Secretary of Defense. Prior DARPA work for the Copper Canyon program was funded from project ST-05 in Program Element 62301E. A major increase over the amount shown in the FY 1986 summary for this program has occurred since approval of the joint program by the Secretary of Defense.

D. OTHER APPROPRIATION ACTIVITY: All DOD contained within PE 63269, except for SDIO where the program is identified as PE 63224C.

E. RELATED ACTIVITIES:

Prior related activities were individual hypersonic propulsion, materials, structures and aerodynamics exploratory research and development activities in the DOD and NASA. These efforts are now consolidated under this overall PE within DOD for DARPA, Air Force, and Navy. SDIO has a continuing activity addressing technologies for reduced space launch costs. In addition, a planned Memorandum of Agreement between DOD and NASA during FY 1986 will further coordinate inter-agency activities. A joint DOD/NASA senior executive steering group will provide oversight and coordination during the program.

F. WORK PERFORMED BY:

DARPA funding will be combined with joint Air Force, Navy, SDIO, and NASA funding under the planned Memorandum of Agreement. Approximately 85 percent of the work will be conducted by industry and 15 percent by Government research centers. Industry participation will be determined from a source selection activity during the second quarter of FY 1986. Possible participants include General Electric Company, Evandale, Ohio; United Technologies Corporation, Hartford, Connecticut and West Palm Beach, Florida; Boeing Aircraft Company, Seattle, Washington; General Dynamics Corporation, Ft. Worth, Texas; Lockheed Aircraft, Burbank, California; McDonnell-Douglas Corporation, St. Louis, Missouri; Rockwell International, Los Angeles, California; Marquardt Company, Van Nuys, California; Aerojet Techsystems Corporation, Sacramento, California; Garrett Air Research, Torrance, California; General Applied Science Laboratory, Westbury, New York; Calspan Corp., Buffalo, New York; duPont Aerospace, Santa Ana, California; Directed Technologies Inc., McLean, Virginia; Science Application Inc., Princeton, New Jersey;

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #63269E  
USDR&E Mission Area: #530

Title: National Aero-Space Plane Technology (NASP)  
Budget Activity: 1. Advanced Technology Development

H. PROJECTS OVER \$7 MILLION IN FY 1987:

1. Project Description: The goals of this program are to investigate the technological feasibility of an air breathing aerospace vehicle capable of: horizontal takeoff and landing; single stage acceleration to orbit; and sustained endo-atmospheric flight at speeds between Mach 6 and 12. Such a vehicle will have significantly larger payload fractions compared to vertical launch rocket systems because it would burn primarily atmospheric oxygen rather than liquid oxygen. Potential applications include the following: space transport (at a reduced cost per pound of payload into orbit) for civil and military application and as a HyperSonic Transport (HST) capable of reducing long range (over 3000 mi) flight times by factors of four to five. Areas of technical investigation include: advanced propulsion, computational fluid mechanics; hypersonic boundary layer flow; engine inlet/shock wave interactions and flow structure; and other fields such as structures, materials, active cooling and advanced controls related to design of an integrated airframe/propulsion configuration with the required performance. Major emphasis will be placed on the fabrication and test of flight scale engine modules. Significant risk reduction efforts will be applied to thermal protection/cryogenic tanks and other airframe components. These technology activities will culminate in preliminary design studies of a research vehicle by the FY 1989 time period. Following a major technology readiness review in FY 1989, the program will transition to an experimental flight vehicle stage with the objective of demonstrating the goals described above.

2. Program Accomplishments and Future Programs: The technical objective is to determine the feasibility of new methods of propulsion for extremely high speed air vehicles that would have military applications in the 21st century. Critical issues addressed to date include those associated with efficient engine cycle selections, engine combustor, inlet and nozzle designs for minimum losses, vehicle designs having acceptable heating rates, and actively cooled structural concepts and integrated airframe-propulsion aerodynamics. Significant advancements made to date include propulsion feasibility tests, development of structural carbon-carbon materials, feasibility demonstration of Rapid

# FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #63269E  
USDR&E Mission Area: #530

Title: National Aero-Space Plane Technology (NASP)  
Budget Activity: 1. Advanced Technology Development

including regeneratively cooled hot sections, variable geometry inlets, and selected subsystems. In the materials area, a major advance in the state-of-the-art in high strength-to-weight, high temperature materials will be exploited using rapid solidification technology with several candidate alloy chemistry compositions. In the structures area, both 'hot' and 'cold' structures will be addressed as part of the thermal protection system/tank design. Large scale tank components will be fabricated and tested. These various tests will establish the key weight contributions of the vehicle structure using advanced materials, thus providing high confidence in the eventual weight of a flight vehicle.

d. Program to Completion: A major milestone review is scheduled in FY 1989 time frame to determine if the various technologies are sufficiently mature to proceed with a manned demonstrator/research vehicle (Phase 3). DARPA funding in FY 1989 and FY 1990 is planned to transition the program into a flight research vehicle. It is anticipated that management of the program will shift from DARPA to the Air Force in the same time frame, but with continued joint DOD/NASA support.

## e. Milestones:

<u>Last Year's Reported Plan</u>	<u>Current Plan</u>	<u>Milestones</u>
Mid FY 1986	Mid FY 1986	Review detailed advanced engine cycles.
Late FY 1986	Mid FY 1987	Conduct engine Preliminary Design Reviews. Conduct airframe-propulsion vehicle integration reviews.
--	Early FY 1988	Review propulsion component test data and engine designs; conduct engine Critical Design Review.
--	Late FY88 to Mid FY89	Conduct large scale engine ground tests.

FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #63269E  
USDR&E Mission Area: #530

Title: National Aero-Space Plane Technology (NASP)  
Budget Activity: 1. Advanced Technology Development

C. COMPARISON WITH FY 1986 DESCRIPTIVE SUMMARY:

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FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #63269E  
USDR&E Mission Area: #530

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H. PROJECTS OVER \$7 MILLION IN FY 1987:

1. Project Description: The goals of this program are to investigate the technological feasibility of an air breathing aerospace vehicle capable of: horizontal takeoff and landing; single stage acceleration to orbit; and sustained endo-atmospheric flight at speeds between Mach 6 and 12. Such a vehicle will have significantly larger payload fractions compared to vertical launch rocket systems because it would burn primarily atmospheric oxygen rather than liquid oxygen. Potential applications include the following: space transport (at a reduced cost per pound of payload into orbit) for civil and military application and as a HyperSonic Transport (HST) capable of reducing long range (over 3000 mi) flight times by factors of four to five. Areas of technical investigation include: advanced propulsion, computational fluid mechanics; hypersonic boundary layer flow; engine inlet/shock wave interactions and flow structure; and other fields such as structures, materials, active cooling and advanced controls related to design of an integrated airframe/propulsion configuration with the required performance. Major emphasis will be placed on the fabrication and test of flight scale engine modules. Significant risk reduction efforts will be applied to thermal protection/cryogenic tanks and other airframe components. These technology activities will culminate in preliminary design studies of a research vehicle by the FY 1989 time period. Following a major technology readiness review in FY 1989, the program will transition to an experimental flight vehicle stage with the objective of demonstrating the goals described above.

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# FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #63269E  
USDR&E Mission Area: #530

Title: National Aero-Space Plane Technology (NASP)  
Budget Activity: 1. Advanced Technology Development

including regeneratively cooled hot sections, variable geometry inlets, and selected subsystems. In the materials area, a major advance in the state-of-the-art in high strength-to-weight, high temperature materials will be exploited using rapid solidification technology with several candidate alloy chemistry compositions. In the structures area, both 'hot' and 'cold' structures will be addressed as part of the thermal protection system/tank design. Large scale tank components will be fabricated and tested. These various tests will establish the key weight contributions of the vehicle structure using advanced materials, thus providing high confidence in the eventual weight of a flight vehicle.

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## e. Milestones:

<u>Last Year's Reported Plan</u>	<u>Current Plan</u>	<u>Milestones</u>
Mid FY 1986	Mid FY 1986	Review detailed advanced engine cycles.
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--	Late FY88 to Mid FY89	Conduct large scale engine ground tests.

# FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #65898E  
USDR&E Mission Area: 474

Title: Management Headquarters (R&D)  
Budget Activity: 6. Defensewide Mission Support

## A. RESOURCES: (\$ in Thousands)

Project Number	Title	FY 1985 Actual	FY 1986 Estimate	FY 1987 Estimate	FY 1988 Estimate	Additional To Completion	Total Estimated Cost
	TOTAL FOR PROGRAM ELEMENT	11,141	12,148	12,200	13,300	Continuing	N/A

B. BRIEF DESCRIPTION OF ELEMENT AND MISSION NEED: This program element provides funds for payment of salaries to civilian employees and for administrative support costs of the Defense Advanced Research Projects Agency (DARPA). This funding provides for the personnel compensation and benefits for civilians assigned to DARPA as well as costs for building rent and security, travel, supplies and equipment, communications, printing and reproduction. In addition, funds are included for reimbursing the Military Services for administrative support costs associated with contracts undertaken on the Agency's behalf.

C. COMPARISON WITH FY 1986 DESCRIPTIVE SUMMARY: The FY 1987 funding increase reflects inflation costs and increase in Building Rent.

D. OTHER APPROPRIATION FUNDS: None.

E. RELATED ACTIVITIES: Not applicable.

F. WORK PERFORMED BY: Civilian and military personnel assigned to the Defense Advanced Research Projects Agency and by DARPA Agent personnel operating within the Military Services.

G. PROJECTS LESS THAN \$7 MILLION IN FY 1987: Not Applicable.



# FY 1987 RDT&E DESCRIPTIVE SUMMARY

Program Element: #65898E  
USDR&E Mission Area: 474

Title: Management Headquarters (R&D)  
Budget Activity: 6. Defensewide Mission Support

## A. RESOURCES: (\$ in Thousands)

Project Number	Title	FY 1985 Actual	FY 1986 Estimate	FY 1987 Estimate	FY 1988 Estimate	Additional To Completion	Total Estimated Cost
	TOTAL FOR PROGRAM ELEMENT	11,141	12,148	12,200	13,300	Continuing	N/A

B. BRIEF DESCRIPTION OF ELEMENT AND MISSION NEED: This program element provides funds for payment of salaries to civilian employees and for administrative support costs of the Defense Advanced Research Projects Agency (DARPA). This funding provides for the personnel compensation and benefits for civilians assigned to DARPA as well as costs for building rent and security, travel, supplies and equipment, communications, printing and reproduction. In addition, funds are included for reimbursing the Military Services for administrative support costs associated with contracts undertaken on the Agency's behalf.

C. COMPARISON WITH FY 1986 DESCRIPTIVE SUMMARY: The FY 1987 funding increase reflects inflation costs and increase in Building Rent.

D. OTHER APPROPRIATION FUNDS: None.

E. RELATED ACTIVITIES: Not applicable.

F. WORK PERFORMED BY: Civilian and military personnel assigned to the Defense Advanced Research Projects Agency and by DARPA Agent personnel operating within the Military Services.

G. PROJECTS LESS THAN \$7 MILLION IN FY 1987: Not Applicable.